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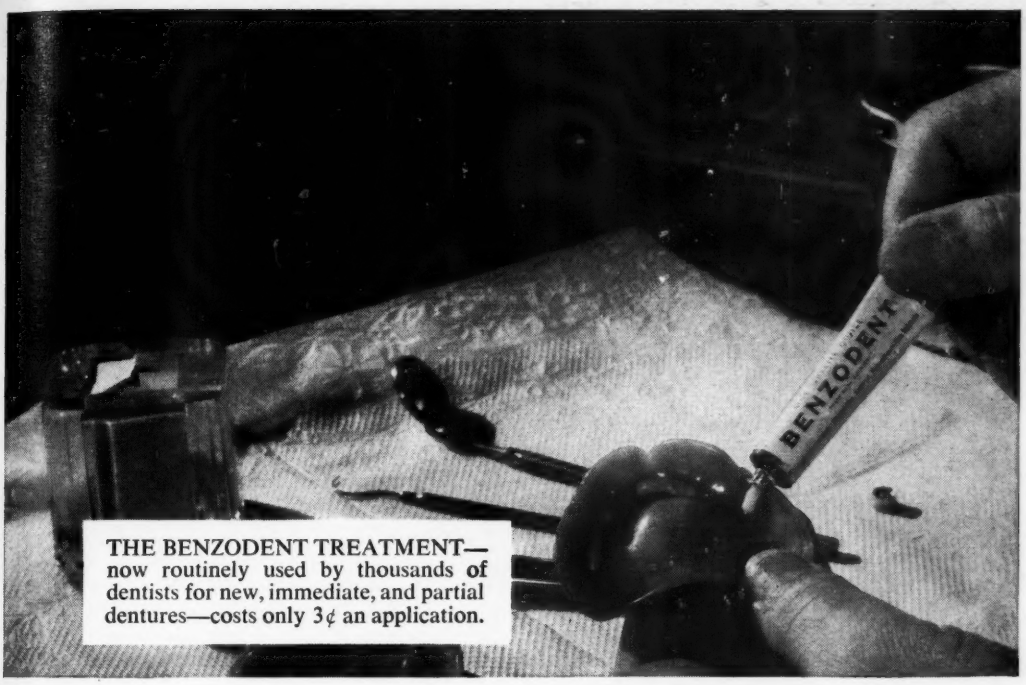

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THE JOURNAL OF PROSTHETIC DENTISTRY

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THROUGH THE EYES OF THE EDITOR

L. E. Kurth has written one of the most stimulating and thought-provoking articles we have seen for a long time. It is impossible to discuss all of the facets of it in the allotted space. It is worth a thorough study, whether one agrees with it or not. He believes that the present concept of balanced occlusion is based upon geometry and articulator movement, and that this is an incorrect approach to the problem. He criticizes this concept but admits that it does "work clinically." He suggests that there may be "other or better [types of] occlusion to which our patients can conform." He criticizes the adjustment of occlusion on the articulator because it is described in terms relating to the articulator, and because of the known deficiencies of the existing articulators. He also criticizes the use of a central bearing point for adjusting occlusion in the mouth. That the central bearing point can introduce errors if it is incorrectly used for this purpose cannot be disputed, but if it is correctly used with an understanding of the nature of these errors, it can be helpful in stabilizing dentures during the occlusal adjustment.

He criticizes the assumption that the "condylar guidance is the only fixed factor" of occlusion. He fails to take into consideration the *reason for* the specification of the five factors of occlusion as they are commonly listed. Kurth states, "We decided to make other experiments to show that the condyle path records can be changed." Regardless of the results, all research should be done with the attitude of *finding out* rather than *proving*. If the facts are learned, the results will speak for themselves without inviting the stigma of bias. In these experiments, a central bearing point and central bearing plates of varying shapes were used. He found that the condyle path tracings were different for each occluding surface. This was to be expected because the various contacting surfaces caused the mandible to rotate to greater or lesser degrees in these various movements. This variation in vertical opening would rotate an irregularly shaped condyle and an unevenly thick meniscus into different relations to each other and to the articular eminence. The variations in the tracings made at the incisor point are also easily explained when one realizes that those made in the frontal plane are almost entirely in the control of the guiding plane (the surface contacted by the central bearing point), and that those made in the horizontal plane are two dimensional projections of three dimensional movements. Tracings can be interpreted differently according to the viewpoint. Tracings are of practical value only when they are used to locate definite jaw relations at specified jaw openings.

Checkbites are used to transfer specific positional relations. There can be no doubt that checkbites will record varying jaw relations when the vertical separation of the jaws is varied. We should not try to use these techniques for purposes other than those for which they are intended. Kurth asks, "If the condyle path, as registered by a graphic tracing or checkbite, is not constant . . . . how can it be used for functional or chewing movements?" The answer is simple. When the teeth are separated for chewing, their relation to each other is relatively unimportant, but when they do contact (and they do many times a day), they

must contact at the vertical jaw separation which was established *before* the checkbite was made. At *this* point, the checkbite is accurate.

Kurth's concern about the relation of the chewing cycle to the Gothic arch is unwarranted. He points out the need for the indication of the "plane of reference" of these tracings. He should also point out the need for a recognition for the effect of the projection of three dimensional movements onto two dimensional records which produces a distortion of the records. This same distortion occurs when functional movements are photographed (Fig. 12) and in addition, the direction of approach to centric occlusion is not a determining factor until teeth contact. A similar photograph to Fig. 12 *could* be produced if the articulator was moved by the demonstrator in the same way as the jaw was moved by the subject. This would require that an opening movement be produced which includes a glide of the condyle mechanisms. Similar distortion of the photographic records would result. Unless the mandible can rotate to a position distal to centric relation *while some tooth is in contact,* it is of no concern in the arrangement of teeth. The only consideration is that the occlusion be developed so that there is complete harmony between all the factors, teeth, temporomandibular joints, and musculature whenever and wherever they may contact within the functional range.

Kurth suggests the use of a reverse or anti-Monson curve of the occlusal pattern which would "aid in the stabilization of the lower denture" at the expense of the upper denture. He does not attribute any value to balancing teeth because he could not "detect any wear" on plastic teeth when they were arranged in this manner. This is not a sound scientific method. It has been demonstrated that plastic teeth wear away more from food abrasion than from rubbing over each other. Also, a recent report by Yurkstas and Emerson (see pages 168-174) shows that balancing tooth contacts are made even more consistently than are working side tooth contacts. The conclusion "most geometric ideals of occlusion will function for the patient" seems significant.

A. A. Yurkstas and W. H. Emerson have studied the contacts made by teeth during mastication by means of electronics. The results of their experiments indicate that one of the frequently quoted statements, "Enter bolus, exit balance" (Prime), is not valid. They found that even with flat cusp teeth, contacts were made on the balancing ramps much more frequently than on the teeth on the working side. They point out the variations in contacts made on the working side by different patients, and in various tests on the same patient. On account of the influence of this type of study on the current concepts of occlusion, this work should be extended to cover other types of teeth. It seems sufficiently important that others should make similar tests. In future tests, a thorough analysis of the occlusion of the teeth should be made to correlate with the results, and with the *reason* for the choice of side to chew on by the patient. It is possible that patients *choose* to chew on the side opposite a premature balancing contact. If a sufficient number of experiments such as are reported here are made *with an open mind,* it will be possible to remove one more problem from the realm of "opinion or conjecture" and place it in the list of "facts."

Friedrich Hesse described some very interesting experiments in jaw movements in 1897 which are modern enough to be reported today. Victor H. Sears' translation of this article should point out the fact that we should be very careful when we claim to have something new.

George Wood Clapp takes issue with A. O. Chick about the accuracy of Gysi's tracings of mandibular movement. While this controversy could conceivably go on indefinitely, it seems to me that one factor is apparently being overlooked by most who are studying mandibular movement. Most of the studies are made of the *boundaries* of movements. These are important because they must be accommodated for in dentures. The boundaries of movement (and thus the tracings) may vary from individual to individual and provide conflicting evidence. It is also important, however, that many other movements (and paths of movement) may occur within the boundaries of movement. The paths *within* the boundaries will vary with the position the mandible is in when the movement is started.

Morris J. Thompson has suggested a method for achieving cuspal coordination in fixed restorations made out of the mouth. The procedure involves the making of accurate jaw relation records in the mouth and reproducing the relations on an adjustable articulator. The restorations are provided with cuspal harmony on the articulator, and these relations are modified in the mouth to correct for those variations which cannot be duplicated on the articulator. He emphasizes the importance of occlusal anatomy and shearing cusp forms. It is unfortunate that more dentists do not think of the mouth in its entirety when they make partial restorations by fixed methods. If this basic philosophy was followed carefully, the vertical dimension of occlusion would not be progressively reduced as fixed restorations are placed, first on one side, then on the other. This sequence follows even as restorations are placed in single teeth, and over a period of time the vertical overlap of all of the teeth becomes greater as the sulci become deeper. These changes cause lateral forces against the inclined planes of the teeth to become greater, and the loss of the teeth from periodontal disturbances is the eventual sequel. This could be avoided by giving the masticatory unit, as a whole, its proper attention.

A. A. Nelson introduces the symposium on the control of condyle relations in the mandibular fossa by listing the early work on this subject. Detailed discussions of the various phases of the problem are discussed by other participants in the symposium.

Oliver C. Applegate recognizes the loss of space between the ridges in the posterior part of the mouth when only anterior teeth remain. He attributes this partly to changes in the bones and partly to condyle migration. He suggests six points to be noted in the evaluation of this loss of inter-ridge space which will determine the treatment.

Ralph H. Boos discusses the basic factors of jaw position and compares the efficacy of various recording procedures. He suggests that the musculature is the predominating factor to be considered in recording jaw relations because it is more likely to be normal than the temporomandibular joint, the occlusion or the bone and soft tissue. On this basis he recommends the physiologic rest position of the mandible as the diagnostic reference position.

Louis S. Block emphasizes the importance of "conditioning" the patient for intermaxillary relation records, and describes the techniques for doing it. He recognizes the fact that temporomandibular joints may be unhealthy or injured and thus not be in a condition for a true registration of jaw relations. It is no more logical for dentists to start building dentures for patients at their first appearance in the dental office than it is for the surgeon to operate on every patient on an emergency basis. Proper treatment of patients before impressions and jaw relation records are made will save time and make better dentures possible.

J. Chaignon Brown describes several articulator mechanisms for inducing condyle migration and tells of the technique he prefers for accomplishing this purpose. He prefers the tap-tap method for correcting the condyle position over the purely mechanical means. It seems sound to make centric jaw relation records after the condyles have been placed in a harmonious position in relation to the other structures in the temporomandibular joint.

Victor H. Sears describes several methods for measuring changes in position of condyles. Some are simple, and others are more complex or are subject to errors of interpretation. The condyle migration recorder which he describes is certainly an excellent diagnostic and research instrument which opens up wide avenues for investigation.

Victor N. Jaffe describes his technique for building dentures. His use of a weighted tray for making the lower final impression has interesting possibilities. The occlusion is developed by means of a functionally generated path similar to that suggested by Meyer. This procedure requires extreme care and patience for its successful use and may be subject to errors in centric relation if it is not properly carried out. The fact that the patient "chews" to develop the path invites movement of the bases along with the soft tissues. This can produce errors if it is not guarded against.

Linden F. Edwards points out the lack of an adequate description of the edentulous mandible in the standard textbooks on

human anatomy. His description is detailed and accurate. It should be helpful to those who are concerned with the changes in the bone which occur under dentures. The terminology he suggests should help to clarify the problems involved in making impressions. The changes in the condyloid and coronoid processes which he points out are probably responsible for some of the difficulties involved in restoring the vertical dimension of the face, and, at the same time, maintaining a satisfactory mechanical relation of the ridges.

Harry M. Bohannan reports his analysis of the mucostatic principle. This essay was one of two which were awarded the first prize by the committee of judges for the American Denture Society Essay Contest for dental students. The history of the mucostatic principle is an interesting background for the discussion of the various factors in the retention of dentures. In simple terms, the principle is based upon intimacy of contact of denture bases against the tissues, without displacement of the tissues. An objective appraisal is made of the principle as it relates to the retention and stability of dentures and to the underlying biologic factors. He includes some excellent ideas regarding the proper adjustment of dentures, although we do not agree that adjustment of occlusion can be done satisfactorily in the mouth. His conclusion that over-enthusiasm of some of the followers of the principle has worked against its acceptance seems to be true. However, it should be borne in mind that there are many interpretations of the principle by different authors.

Fairfax Moody Windecker, Leo J. Windecker, and Robert H. Kirkpatrick integrate the services of the dentist, physician, and anesthesiologist in the immediate denture service they describe. This seems like a good thing to do, but it does make a big thing of an operation that can be done in a dental office. They suggest that all remaining teeth be removed and the denture be inserted with the patient under hospital care. This is sound when such extensive surgery is to be done. However, the advisability of such a procedure is open to question on the basis of the foundation for the denture. It must be admitted that the support supplied to a denture by a blood clot-filled tooth socket is not of much value, at least temporarily. Changes will occur at these sites more rapidly than in other areas in the mouth. The areas where teeth are removed are only approximated by the best prosthetic and surgical procedures. These areas invite edema which further complicates the maintenance of proper occlusal contacts during the early denture wearing experience of the patient. These problems are reduced when most of the healing has occurred before the impressions are made. The techniques for anesthesia seem to be quite thorough and sound.

Milton T. Edgerton and James E. Pyott show how the surgeon and prosthodontist can work together in solving the problems associated with the reconstruction of the jaw in the treatment of malignant lesions of the oral cavity. This cooperation is essential to the best interests of the patient. The prosthetic restorations described by Dr. Pyott are very ingenious and are well worth study. The dental profession has a major responsibility in the treatment of cancer of the mouth as well as in its early diagnosis.

Donald B. Giddon, M. E. Driesbach, Carl Pfaffman, and R. S. Manly report the results of their studies of the relative ability of patients with natural and artificial dentures to judge the sweetness of solid foods. Tests were made with and without time limitations. The results show that patients with artificial dentures require a longer time to judge sweetness of solid food. This is probably due to the reduced masticatory efficiency of these patients which would prevent rapid solution of the sugar in the saliva. No comment was made about the kind of teeth the patients were wearing or about their adequacy. The results apparently indicate that artificial dentures do impair the ability of patients to make distinctions between slight differences in sweetness. The results differ from those of some others who have studied this problem, but this may be due to the difference in the methods employed and the food tested.

Henry A. Collett and Dennie L. Briggs suggest some psychologic reasons why certain patients fail to seek service on their dentures when it is really needed. The cases they report illustrate patients' attitudes that

get them into serious denture difficulty. An understanding of the psychologic attitudes of patients can help us to guide the patients properly.

Carl W. Fairhurst and Gunnar Ryge report on their studies of the effects of a tin-foil substitute on acrylic resins. The results of this work have practical bearing on the techniques currently in use in the processing of dentures. The authors may be criticized for using only one tin-foil substitute for most of the tests, but the results indicate that the use of these substances is certainly open to question. The crazing of acrylic resins processed in contact with tin-foil substitutes is well established. They show quite clearly that a denture processed with tin foil on both sides is more accurate than when a tin-foil substitute is used on both sides, and that a denture processed with a tin-foil substitute on one side and tin foil on the other is the least accurate. We agree that the warpage produced by the use of tin-foil substitutes is more significant in the final results than is the lineal shrinkage. This difference has been observed clinically.

Leo Talkov discusses the problem of pulp protection in crown and bridge prosthesis. The importance of adequate pulp protection cannot be overemphasized. The various agents used for this purpose are discussed on the basis of what they are supposed to do and the way they should be used. The choosing of the agent to produce the desired effect seems logical.

—Carl O. Boucher

BALANCED OCCLUSION

L. E. KURTH, D.D.S.

Chicago, Ill.

BALANCED OCCLUSION has been defined differently by various investigators depending upon their point of view. "Balanced occlusion involves a definite arrangement of tooth contacts in harmony with the mandibular movements,"[1] and "If the positions, dimensions and occlusal surfaces of the teeth are such that during functional jaw movements, mandibular cusp blades contact maxillary cusp blades throughout the dentures, those dentures can perform their masticatory function most effectively, and their occlusion may be termed a 'physiologic occlusion' or 'balanced occlusion, ' "[2] and "the necessity of 'balanced occlusion' or distribution of occlusal stress over the greatest possible supporting area has for many years been emphasized by both prosthodontists and periodontists."[3]

Various techniques have been promulgated to achieve the objectives of these definitions for both natural and artificial teeth. A diligent analysis of the literature pertaining to occlusion has shown that many investigators have formulated certain conclusions which were based on questionable geometric theories, and on hypothetical articulator movement, and bearing little, if any, relation to observed human dentition. From Bonwill in 1864, who has been called "the father of anatomic (balanced) three point contact occlusion"[4] to the present time, all the theories which were studied seemed to be based upon the assumption that the articulator moves similar or equivalent to the mandible.

Our modern concepts of balanced occlusion for both natural and artificial teeth are based primarily on the geometric theories of Gysi. His mathematical theories are beautifully illustrated and symmetrically perfect, but are based on a study of nonfunctional mandibular movements. For instance, as a result of these studies of mandibular movements he was able to show geometrically the variability of rotation centers and their asymmetrical location. Yet he devised an articulator with symmetrical fixed rotation centers, and assumed this machine to be an ideal solution for a complex anatomic situation. This dependence on his articulator is apparent, for he also carved the occlusal surfaces of his so-called anatomic teeth on this articulator, and didn't even use natural teeth as a guide. A model of shark's teeth (Fig. 1), cut out "the primary masticatory surfaces of the maxillary bicuspids and molars."[5] His ideas of a symmetrical balance based on geometry (Fig. 2) greatly influenced the thinking of the men who followed him. Space does not permit the discussion of all the individual techniques of the earlier investigators of the twentieth century, so I will limit my discussion to an examination of some of the current concepts of balanced occlusion for both natural and artificial teeth.

Read before the Midwinter Meeting of the Chicago Dental Society Feb. 10, 1953.
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THEORIES OF OCCLUSION

The various groups of occlusal theorists who follow the basic concept of Gysi have devised different geometric ideals of what constitutes a normal occlusion. This psychologic phenomenon of an individual, or a group, to determine mentally what constitutes an ideal for a certain procedure or form is widespread. Needless to say, all individuals or things do not come up to these ideals. What is beauty to an eskimo is entirely at variance with the same ideal to an African pygmy or an American. Everyone is entitled to his ideals, but difficulty will always ensue when an individual tries to impose his ideals on the entire population, with the implication that this is the only ideal, or the only way to perform a certain operation, especially when the ideals cannot be supported by scientific facts.

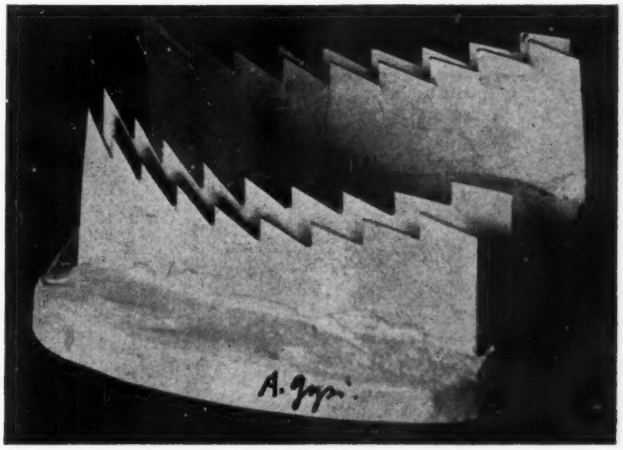

Fig. 1.—Gysi's model of shark's teeth which he used for the formation of his anatomic posterior tooth molds[5] (Courtesy Dentists' Supply Company).

This is exactly what has occurred in the study of occlusion. Various groups have set up ideal occlusions based upon purely hypothetical assumptions, and any individual who dares to question this ideal is attacked as being ignorant or not worthy of consideration. It would be foolish to say that these various theories and techniques do not work clinically, but that there may be other or better occlusions to which our patients can conform. An attempt is made to support these various ideal occlusions with a pseudoscientific background as by saying "Evolution, or heredity, has planned through the ages to deliver to each of us moderns a masticatory assembly capable of multiple cusp contacts in all positions within the chewing range of the mandible."[6] Then on the same page, "The fact that a large percentage of modern human beings do not have complete bilateral balance is no evidence that mankind is not intended to have it. A still larger percentage have some balancing contacts." It is agreed that the full impact of a writer's thoughts can be distorted by short quotations taken from his article, but these two are definitely not consistent. If we agree with the first statement, the second statement should also agree, for it is just as scientific to state that it is the plan of evolution that mankind is not intended to have a bilateral balance in occlusion. These refutable statements which are used

as an assumption to justify an individualized concept of an ideal occlusion can be multiplied. Thus we have, "49 assumptions to this hypothesis of spherical congruency for a theory of occlusion."[7] "I wish to state that there never has been, and there never will be, an occlusion which conforms to the accuracy demanded by a geometric asumption."[8] Brodie in commenting on this statement says, "the question immediately arises as to whether we are justified in taking such a mechanistic concept as a Law of Nature. Are we justified as practitioners in accepting such a law as a practical ideal to the extent of conforming our clinical procedures to it?"[9]

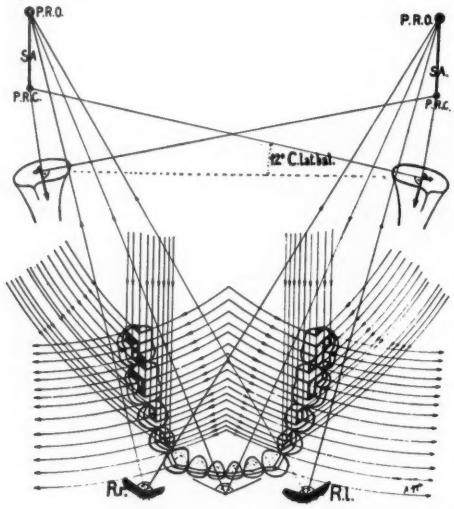

Fig. 2.—Gysi's geometric basis for occlusion is apparent from his description of this illustration. "This is one of the simplest of many geometrical constructions which have shown that the tooth forms arrived at by means of the shark's teeth are geometrically and mathematically correct. In making such studies it is necessary to record two Gothic arches like those shown anterior to the cuspids, and from them the rotation points may be determined by the erection of axes at right angles to each half of each Gothic arch. Lines parallel to the sagittal plane are drawn on each side of the median line to indicate the protrusive movement of the mandible. If, with the rotation points as centers, arcs like those shown in this drawing are inscribed on each side of the median line, it will be found that the location and the direction of the grooves are established, and that the location, form, area, direction and inclination of each of the occlusal facets on the teeth are determined by purely geometrical means. A few of the facets have been shaded here to show how this is done." (Courtesy Dentists' Supply Company.)[5]

TECHNICAL INTERPRETATIONS

After accepting these various geometric ideals, these men have followed logically with a technique to approach their ideal in the human dentition or artificial reconstruction. The majority of these techniques have assumed that a hinge axis exists for pure opening and closing of the mandible and the immutability of the condyle path, and that the mandible moves similar or equivalent to the articulator of their choice.

McCollum[10] has demonstrated that patients can be trained to open and close their mandible on an apparent point of nonmovement, located in the region of the condyles, which he calls the hinge axis. The location of this point is the foundadation of his entire technique and is the criterion used to determine centric maxillo-

mandibular relations. For example, if the occlusion of natural dentition is being diagnosed, and if it does not conform to the centric relation, as determined by the hinge axis in its mounting on the articulator (which is adjusted by the Gothic arch) that patient is said to have a malocclusion. Then we find another author[11] subscribing to this theory, writing, "Patients with a natural dentition always will close their jaws in centric occlusion. As judged conservatively by the author this centric occlusion, in fifty per cent of all patients, is not a true centric or hinge occlusion but a convenience bite."

I am just as scientific by using these questionable figures to say that those occlusions which function on the hinge axis are the ones in malocclusion, and if the figure of 50 per cent is a conservative one, by mere predominances of numbers, the hinge axis centricity theory would be wrong. Anderson,[12] by means of the cephalometer, demonstrated that in the short distance from physiologic rest position to centric occlusion only 50 per cent of the patients studied moved their mandibles as hinges. Posselt,[13] in commenting on the results of his studies in the movement of the mandible from rest to the intercuspal position, says "I can only consider that these results show that the mandible performs a bodily movement between the two positions. The axis of such a movement cannot at any rate pass through the condyles." Dr. Feinstein and I[14] found that there was an area of apparent nonmovement in the region of the condyles of approximately 2 mm., and that there was not one single definite point which would serve as a hinge axis. Craddock[15] says, "But the search for the axis, in addition to being troublesome, is of no more than academic interest; for it will never be found to lie more than a few millimeters distant from the assumed center in the condyle itself."

Amer[16] shows both the asymmetry of size, shape, and angulation of the left and right condyles (Fig. 3). He also demonstrates that a line bisecting the two condyles, as a hinge axis would do, would invariably pass through the smallest portion of the condyle. This would be contrary to all ideal engineering principles. The value of the hinge axis as an aid to obtaining a balanced occlusion can be questioned.

Schuyler[17] presents a very complete geometric procedure, based on the articulator, to obtain a balanced occlusion in both natural and artificial teeth. His formula for the removal of occlusal interferences is reduction of the buccal cusps of the upper and lingual cusps of the lower teeth as viewed in the frontal plane, and the reduction of the mesial of the upper cusps and distal of the lower cusps as viewed from the sagittal plane. (BU-LL and MU-DL) Any cuspal interferences would have to follow this pattern because that is exactly the way the articulator moves if it has an adjustable condylar path. It doesn't make any difference what technique is used to set these condylar adjustments, the center for the lateral and the protrusive movements can be demonstrated to arise in an area above the upper member of the articulator. (The anatomic designation on the patient would be in the region of the glabella.) Consequently, the use of the articulator freezes this motion and the BU-LL cusps would come into interference first; as it is the upper member of the articulator which moves, the interference which would be noticed on the casts in a lateral movement would be located on the mesial of the upper and the distal of the lower cusps. This movement on the articulator is, of

course, the reverse of what occurs when the human mandible functions and even "the movements of an articulator are not the same when the joint slots are in the upper part as when they are in the lower part."[18]

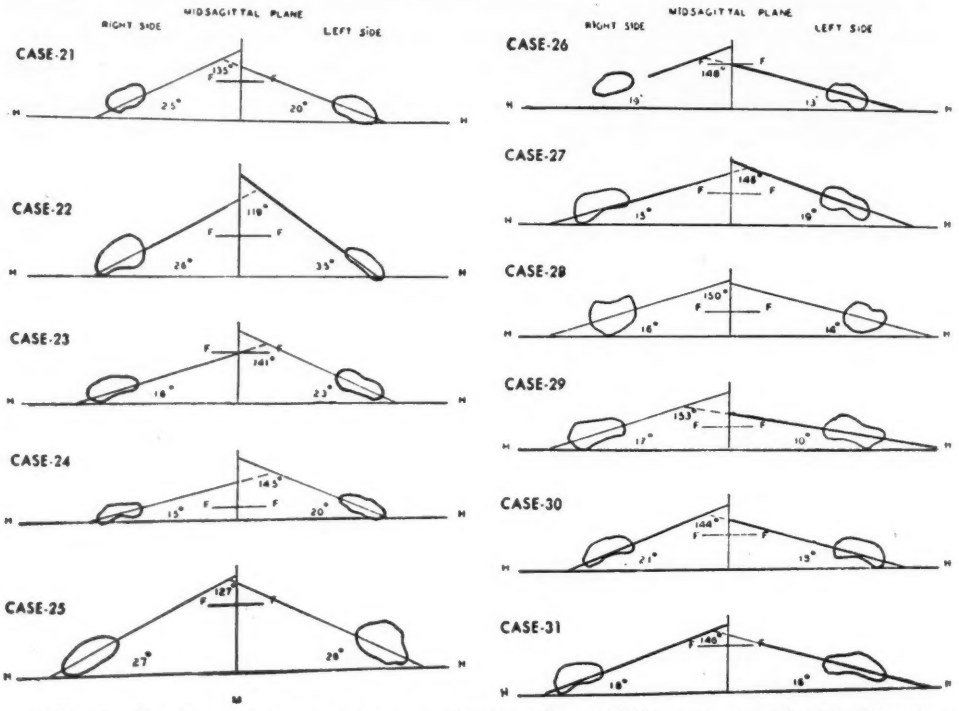

Fig. 3.—Tracings of roentgenograms showing the variations in condyles.[18] (Courtesy J.A.D.A.)

Some techniques fix a central bearing screw to the lingual surfaces of the mandibular teeth, either natural or artificial, to contact a flat plane in the palatal region as an aid to locate occlusal interferences. This method is not any more accurate than the articulator for this purpose, because the mandible will follow the dictates of the flat plane and central bearing screw. The direction of movement, which is engendered under these conditions, will always be upward and outward when viewed in the frontal plane. Shanahan[19] demonstrated (Fig. 4) that occlusion rims with carborundum and plaster contacting surfaces with a central bearing screw moving upon a flat plane to maintain the vertical dimension would develop a space between them, when nonfunctional mandibular movements were made by a patient.

The movement of the articulator and the condylar guidance of the patient is assumed by many men to be fixed or constant. "Condylar guidance is the only fixed factor of articulation. It cannot be changed by the dentist or dental restorations. The four other factors are all controllable factors which can be changed and modified by dental operations."[20] Anatomically speaking, the condyle path determined by the temporal bone cannot be changed, but if the records obtained from the patient to set and adjust the condyle paths of the articulator can be altered,

the "one fixed factor of articulation" is not constant, and cannot be assumed to be a logical foundation upon which the superstructure of an ideal occlusion can be based.

The determination of the value of the condyle path has been questioned in the past. From the time of Christensen to the present, experiments have been made which demonstrate that the angle of inclination of the condylar path on the articulator can be altered by different checkbites obtained as records from the same patient. We decided to make other experiments using modern techniques to show that the condyle path records can be changed. These experiments were performed on patients with a normal occlusal relationship and a complete complement of natural teeth. Clutches were constructed over accurate casts of the patient's teeth, and so devised that they would not interfere with the normal occlusal relationships. The lower clutch supported a Gysi Kinematic face-bow and a tracing plate in the horizontal plane at the incisor point. The upper clutch supported a condylar tracing plate in the sagittal plane, a tracing plate at the incisor point in the frontal plane, and styluses to make graphic tracings. A central bearing screw on the lower clutch contacted planes which could be inserted in the palatal region of the upper clutch.

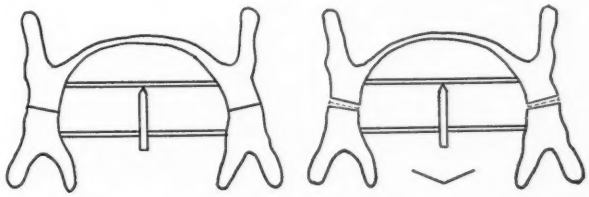

Fig. 4.—The left diagram depicts a frontal view of maxillary and mandibular occlusion rims with abrasive surfaces ground into absolute contact by nonfunctional movements of the patient. Then a central bearing screw is inserted into the lower occlusion rim to contact a flat plane attached in the palatal region of the maxillary occlusion rim. The flattened V under the right diagram is the general direction of movement which will occur under these conditions. It can be seen that although the vertical dimension was maintained, the occlusal surfaces wore out of contact when the patient again made nonfunctional movements. (Based on Shanahan's discovery.)

The difference between this experiment and the conventional method of obtaining tracings is that the central bearing screw could be made to contact surfaces of various degrees of curvatures, from a flat plane to a convex or a concave surface. It is questionable why Phillips used a flat plate for it to contact in making positional registrations. Stansbery, in his earlier work, used a convex plate, but he is now using a flat plate to obtain checkbites for setting his instrument. It must be remembered that the natural teeth move upon inclined planes on both right and left sides in both functional and nonfunctional movements which make an angle open downward of approximately 120 degrees. Consequently, the use of a central bearing screw against a flat plate does not follow this normal occlusal pattern of direction of movement.

The clutches with their attachments were rigidly cemented to the patient's teeth. The stylus on the face-bow was adjusted to the so-called hinge axis (which I term an area of apparent nonmovement of the condyles). Condylar tracings were

then obtained in the sagittal plane, while tracings were made at the incisor point in both the horizontal and frontal planes. The tracings were recorded with the patient making nonfunctional movements determined by the inclined planes of his teeth; then with the use of the central bearing screw opened to remove all occlusal contact and moving successively on a flat plane, a convex plane of approximately 120 degrees open toward the palate, and a concave plane of approximtely 120 degrees open away from the palate (Fig. 5). It cannot be denied that the mandible, with the use of a central bearing screw, can move on all these various planes, and it is an accurate means of testing the immutability or constancy of the condyle path, as graphically traced by mandibular movements of the patient. If the condyle path is constant as registered, we would logically expect to find that the condylar

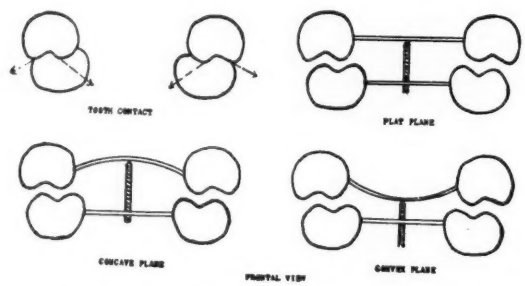

Fig. 5.—Frontal view of the four possible surfaces upon which nonfunctional movements of the mandible can be made. (1) Tooth-to-tooth contact, where the direction of mandibular movement is determined by the inclined planes of the maxillary teeth as depicted by the arrows. (2) The use of the central bearing screw riding upon a flat, (3) concave, or (4) convex plane determines other and different directions of mandibular movements.

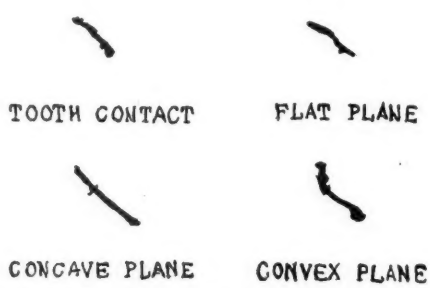

Fig. 6.—Sagittal view of right condyle. The wide variance of condylar angulation traced graphically in the sagittal plane from tooth-to-tooth contact as compared to the tracings obtained a flat, concave, and convex plane.

tracings do not change from one set of conditions to another. Fig. 6, however, clearly demonstrates that this assumption is not correct, and that the graphic tracing of the direction of the condyle path in the sagittal plane is definitely altered by changing the movement, as directed by the inclined planes of the cusps in tooth-to-tooth contact to the central bearing screw moving on a flat, concave or convex plate.

Fig. 7 graphically portrays the differences in angulation for the Gothic arch tracing on the horizontal plane at the incisor point. It varies from about 159 degrees for tooth to tooth contact, to approximately 138 degrees for the central bear-

ing screw and a flat plane, to 152 degrees for movement on the concave plane, and 149 degrees for a tracing obtained with the use of a convex plane. It must be remembered that the patient's mandibular movement traced each one of these tracings, and that each set would give the operator a different occlusion, or a different concept of balance, if the same technique was used for the grinding in of natural teeth, or the setting up of artificial teeth. These differences are also clearly seen in the graphic tracings in the frontal plane of the incisor point in Fig. 8. The two tracings which were approximately equivalent in direction were the tooth-to-tooth contact when compared with the tracings obtained when the central bearing screw attached to the mandible moved on the concave plane attached to the maxilla. The other tracings are not comparable. Therefore, the condyle path and the Gothic arch are not constant when registered under different conditions, and cannot be considered a fixed characteristic of the masticatory system. Similar results were obtained from four other subjects.

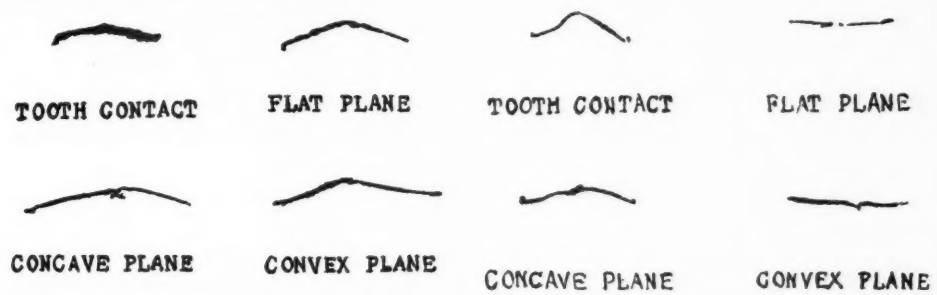

Fig. 7.

Fig. 8.

Fig. 7.—Horizontal view of incisor point. Graphic tracings demonstrating the difference in angulation of the Gothic arch as determined by the various plates upon which the mandible moved.

Fig. 8.—Frontal view of incisor point. Graphic tracings depicting the differences of mandibular movement when determined by the various plates as graphed in the frontal plane at the incisor point.

Similar clutches were constructed and cemented to a normal complement of teeth for another patient. Provision was made to change the maxillary plate, upon which the mandibular central bearing screw moves, from a flat to a concave plane. Using the Stansbery checkbite technique, a centric relation plaster checkbite was obtained with the use of a central bearing screw and a flat plate. The central bearing screw was then opened 1½ mm. to compensate for the depth of the cusps, and another Gothic arch was traced anterior to the first one. Right and left lateral plaster checkbites were obtained on this Gothic arch tracing ¼ of an inch from the apex. The casts were mounted in centric relation on a Stansbery tripod, and the guide paths were set to the right and left lateral positions as determined by the plaster checkbites. The flat plate was removed from the maxillary clutch, and a concave plate of approximately 120 degrees open downward was substituted to simulate the angulation of the inclined planes of the teeth. The length of the central bearing screw on the mandibular clutch was increased to contact this concave plate to preserve the original vertical dimension. The clutches were recemented to the patient's teeth, and another Gothic arch was traced, and another cen-

tric relation plaster checkbite was made. The central bearing screw was then opened 1½ mm., and another Gothic arch was traced by the patient. Right and left lateral plaster checkbites were obtained ¼ of an inch from the apex of the tracing. The centric position thus obtained was identical with the other centric mounting on the tripod. Figs. 9 and 10 (photographed in double exposure) conclusively demonstrate the differences between the lateral checkbites obtained when the flat and concave plates were used. Although centric relation was the same (because the vertical opening at which the centric checkbites were obtained was identical) the differences in the angulation of the guide paths of the tripod clearly demonstrate that the lateral positions were not similar. Dentures, occlusal reconstructions, or a diagnosis could be made scientifically from each of these registrations on the flat or on the concave plate; but which registrations best to determine an occlusion for the same individual? This experiment verifies the fact that the mandibular lateral positions on the condyle path can be altered, irrespective of the apparent constancy of centric relation. The value of an adjustable articulator as an aid to obtaining a balanced occlusion can be questioned.

If the condyle path, as registered by a graphic tracing or a checkbite, is not constant for these nonfunctional movements, as exemplified by the Gothic arch, how can it be constant for the functional or chewing movements? The large majority of the articles written on balanced occlusion do not make any distinction between functional and nonfunctional movements of the mandible. The claim that the mandible in chewing a bolus of food moves as McLean describes it, cannot be substantiated by clinical experiments. "Thus, if the bolus is on the right side of the mouth, the jaw closes in right lateral position. This closure represents the crushing stroke until opposing tooth cusps have contacted through the bolus. Then the jaw starts swinging toward centric relationship, dragging the mandibular denture across the maxillary one, so that many pairs of upper and lower cusps form pairs of shears for cutting food. The jaw normally swings through centric relationship and over to the opposite lateral position, where it swings open and returns to the point of beginning for another crushing and shearing stroke."[21] This is admittedly the description of an articulator supposedly functioning in a working occlusion, or a nonfunctional mandibular glide, but it definitely is not the way the mandible functions in a chewing movement. The movement of the mandible in chewing function is cyclic in nature, and bears no relation to this descripton of an articulator movement.

All investigators who have written recently on the direction of the functional chewing stroke, using many different techniques to trace this movement, have obtained similar tracings of the direction of the functional chewing stroke of the mandible.[22–26] In the frontal plane (to interpret mandibular movement intelligently and scientifically, the plane of reference should be indicated), the chewing movement is elliptic or tear shaped, pointed toward centric relation; in the sagittal plane it is directed elliptically upward and forward toward centric; while in the horizontal plane it is ellipsoidal in shape, posterior to centric relation. Many men do not understand this description of the horizontal view of the incisor point because the Gothic arch represents the complete envelope of nonfunctional movement at a given vertical opening, and they cannot visualize anything posterior to

Fig. 9.

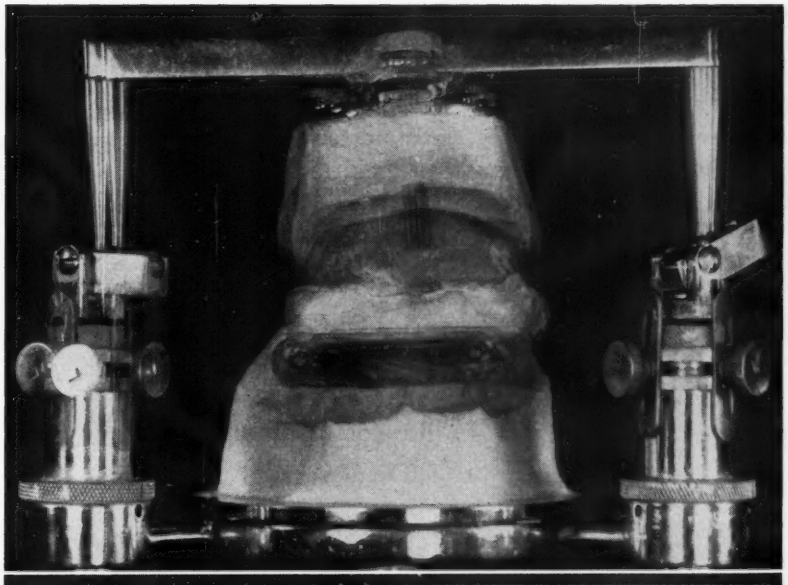

Fig. 10.

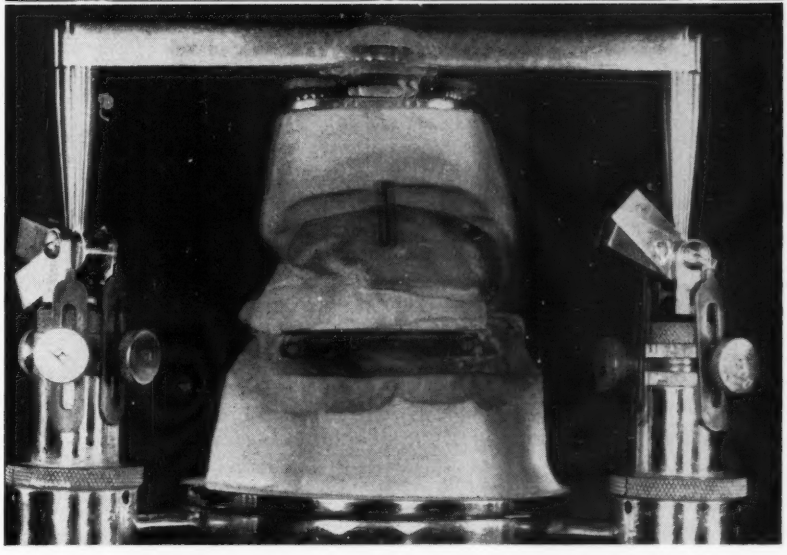

Fig. 9.—Stansbery tripod photographed in double exposure demonstrating the differences between checkbites for the right lateral position taken with a central bearing screw on a flat and concave plate. The movement of the upper member of the tripod depicts the two positions, either one of which could be used as a basis for a balanced occlusion.

Fig. 10.—Stansbery tripod demonstrating the differences between the articulator adjustment for a left lateral position, photographed in double exposure with checkbites made on a flat and concave plate.

its apex. This can be explained as follows: the functional or chewing movements involve rotatory and translatory motions, which means that the vertical opening is changed, but these are photographed on the same plane, and consequently the chewing stroke is photographed posterior to the apex of the Gothic arch (Fig. 11). Stansbery's tracings, for instance, prove this contention, because to compensate for cusp height two Gothic arches are traced on the same horizontal plane. The second Gothic arch is used to determine the eccentric relations, and is made at a greater vertical opening than the first one. It is always posterior in its sense of direction to the original Gothic arch which was used to indicate centric relation.

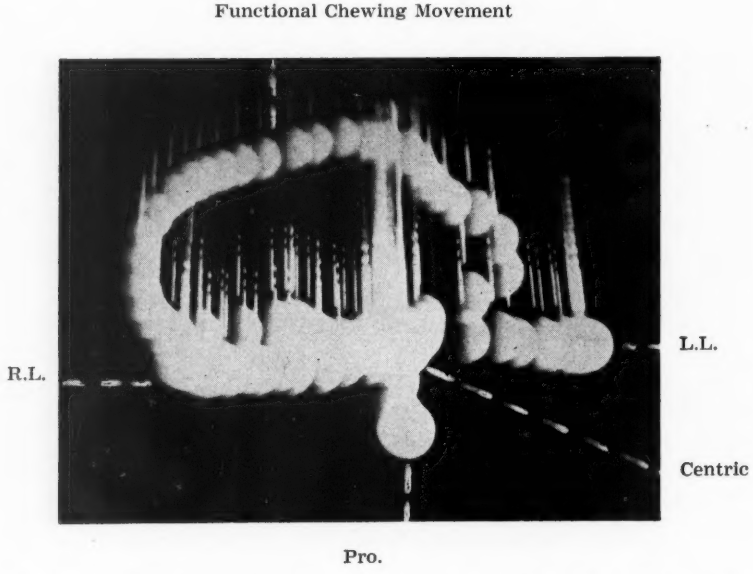

Fig. 11.—A stroboscopic photograph of an indicator located at the incisor point, and referred to the horizontal plane. The functional chewing movement is posterior to centric relation and is not within the included angle of the Gothic arch formed by nonfunctional movements.

The movement of the articulator's guide pin when traced or photographed will always be confined to the included angle of the Gothic arch (Fig. 12). The direction to centric relation on an articulator is from an anterior position posteriorly for a nonfunctional mandibular glide, while the functional or chewing movement of the mandible (as traced in the horizontal plane at the incisor point) is from a posterior position anteriorly into centric. This is the main reason why it is fundamentally wrong to permit an articulator to act as an arbiter for checking interferences in occlusion.[27] When these advocates of balanced articulator occlusion understand the great differences between a functional chewing stroke and a nonfunctional mandibular glide or articulator movement, they invariably justify their contentions by rationalization. They then claim that their patients only chew for a short period of time throughout the day, but make many nonfunctional mandibular movements and that these are the most important. Further assumptions are made by claiming that the gliding movements of the mandible, when they meet occlusal

interference, are an etiological cause of periodontal lesions, or are responsible for loss of stability in dentures. The greatest muscular force the teeth, the periodontium or artificial dentures will have to withstand occurs before the teeth come into contact during a functional chewing movement. It is then that the powerful muscles involved in closing the mandible, the masseter, internal pterygoid, and temporal, exert the greatest amount of measurable force on the occlusal surfaces. Orban[28] has shown that traumatic occlusion which may occur in these movements is not an etiological factor in inflammatory periodontal lesions or pocket formation.

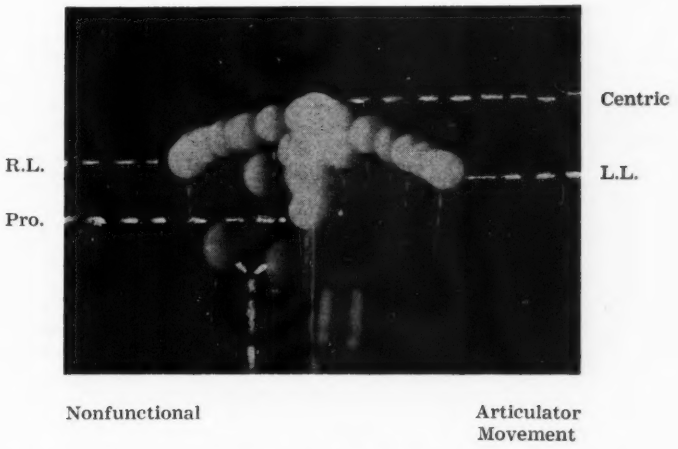

Fig. 12.—A stroboscopic photograph of an indicator located on the incisor guide pin of an articulator, and referred to the horizontal plane. The nonfunctional movements and simulated functional movements are all confined within the angle of the Gothic arch.

Misconceptions of the directions of both functional and nonfunctional mandibular forces on the occlusal surfaces of the teeth are rife in dental literature. Fig. 13 is a diagrammatic, sagittal view of the maxilla and mandible with the general direction of the roots of the individual teeth sketched in. The true vertical of the diagram is represented by the arrow *CD*, the true horizontal by the arrow *AB*. The flat occlusal plane which runs from the incisal edge of the central incisors to the distobuccal cusp of the upper second molar is not parallel to this true horizontal but angles upward and backward from the horizontal at about 10 degrees (line *EF*). Note that the curve of Spee is a digression from this flat occlusal plane. When the mandible is functioning in a chewing stroke, and it is at its limits of opening, both rotation and translation are involved in the condylar region. This is depicted by the solid line drawing of the mandible, while centric occlusion is represented by a broken line. When the mandible closes in function, it moves approximately like the curved solid lines labeled *M* to centric occlusion. These *M* lines are the direction of the resultants of the muscular force applied by all the muscles attached to the mandible and associated with this movement.

When these force lines approach centric occlusion, the force which it represents is applied to the inclined planes of the teeth. This resultant force of the mandible is dissipated at, or near, centric position if a bolus of food is interposed

at right angles to the inclined planes of the cusps. The broken lines *CR* are the direction of the forces which will have to be opposed by each tooth in the sagittal plane. Note that these masticatory forces are extended beyond the limits of the roots of the teeth and are not in an axial direction. If we take the upper first bicuspid as an example, as shown in Fig. 13, there is a force *CR* applied to its mesial inclined plane, and one to the distal inclined plane of the buccal cusp, neither one of which is in an axial direction. The position of the root and its distal inclination is the method used by nature to effect an equilibrium of these divergent forces. The direction of the root of this tooth, and its position in the maxilla, is directly subservient to the function imposed upon this tooth. This sagittal view of the masticatory force *M* has been broken by some authors into components, a vertical component and a horizontal component. They claim that the vertical components are favorable forces and the horizontal components are deleterious forces. They forget that the solid lines labeled *M* are the direction

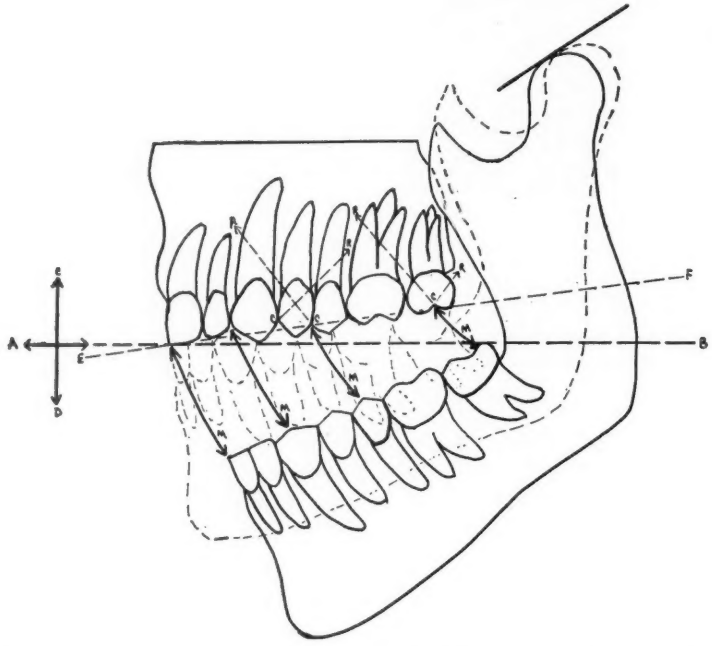

Fig. 13.—A diagrammatic sketch of a sagittal view of the maxilla and mandible in function. Note that the true vertical is *CD* and the horizontal is *AB*. The forces of mastication, or the resultant of the muscular effort, are the arcs *M*. *CR* are the forces applied to the inclined planes of the teeth. There are no perpendicular axial forces exerted on any tooth.

of mandibular force which is already the resultant of many muscular forces which are applied to the mandible. Consequently, the physics is questioned when this force, *M*, is said to have a vertical or horizontal component. I can scientifically give this masticatory force any number of components, vertical or horizontal, or from any angle of the quadrant. Whatever components this resultant is divided into, the fact remains that the direction of *M* is the only force to be contended with by the individual tooth or the occlusal surface of the artificial dentures.

Fig. 14 depicts a frontal *(A)*, sagittal *(B)*, and horizontal *(C)*, view of a mandibular molar tooth in an open functional position, and the direction of the masticatory forces which are applied to bring it to centric occlusion. Note that from a frontal view *(A)* the functional stroke *M* (involving rotation and translation of the condyle) is drawn in a solid line, while the articulator or nonfunctional movements (which are only translatory condylar movements) are broken lines labelled *b* and *w*. Hildebrand[29] measured the magnitude of tooth-to-tooth contact during this movement and found that the average gliding movement into centric occlusion was between 1 and

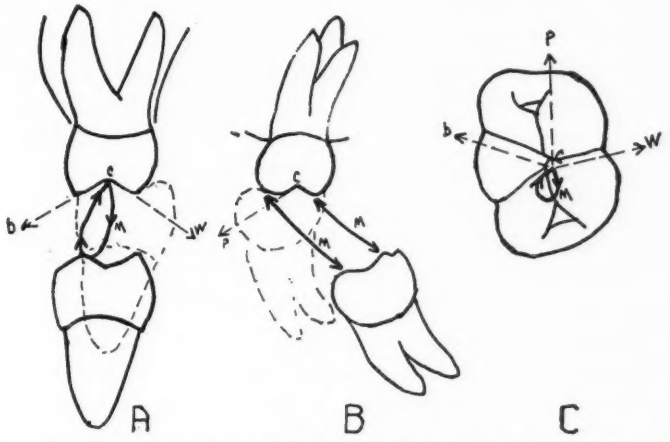

Fig. 14.—A diagrammatic view of a molar tooth in functional movement. *A* is a frontal, *B* sagittal and *C* horizontal view. *M* is the functional masticatory stroke. *C* is centric position, *CD*, *CW*, and *CP* are nonfunctional strokes.

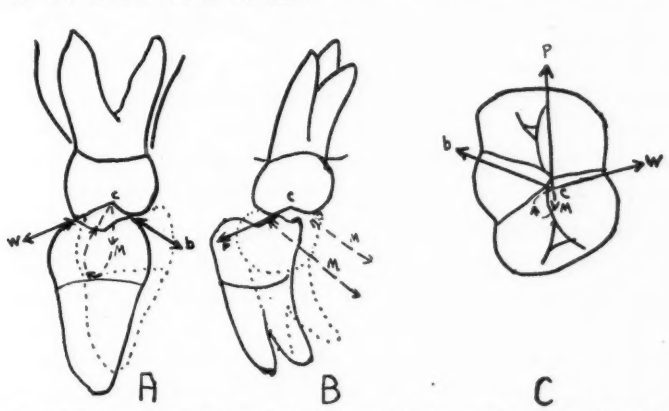

Fig. 15.—Frontal *(A)*, sagittal *(B)*, and horizontal *(C)* views of a molar tooth in nonfunctional movement as determined by the inclined planes of the maxillary tooth. The broken lines *(M)* are the functional movements in the same plane.

2 mm. as measured at the incisor point in the frontal plane; while the gliding into centric occlusion as measured in the sagittal plane amounts "to no more than a few tenths of a millimetre." However it is measured, the direction of movement into centric occlusion, as demonstrated in the frontal plane, is entirely different from the nonfunctional glide *b c w*. The sagittal view *(B)* demonstrates that the force

M is entirely different from that direction found in the frontal plane because of its projection, although it is exactly the same force *(M)* which is demonstrated in *A*. The nonfunctional force, depicted by the broken line *CD*, can be seen to follow the distal inclined plane of the upper mesiobuccal cusp. *C*, the horizontal view, shows the direction of the force upon the occlusal suface of the lower molar. The broken line is the direction of the nonfunctional glide to its balancing, working, and protrusive positions. The elliptical line *M* is the direction of the functional stroke on the cusps. Note in the three views that these nonfunctional movements have no relationship to the functional chewing movement, *M*, except at centric occlusion.

Fig. 15 similarly demonstrates, in the three planes of projection, the comparative cuspal positions in translatory nonfunctional or articulator movements. The great differences between the functional and nonfunctional positions of the teeth can be seen by comparing with Fig. 13.

The unique findings of this study are that all the various techniques in vogue at the present time for balancing occlusion will give excellent results, irrespective of the geometry used as an ideal, if an accurate centric relation is obtained. It is a very debatable assumption that the most damage is done to the periodontium or to the tissues under the dentures during nonfunctional translatory mandibular movements as determined by the occlusion of the teeth. It also is debatable as to what ideal geometric occlusion is the best for each patient. Therefore, I, as well as any other dentist, am entitled to my concept of geometry in relation to balanced occlusion if it has worked successfully in my hands.

Can natural teeth be balanced where no pathology of the periodontium is present, just because the patient's occlusion does not meet with the operator's preconceived geometric ideals of what a balanced occlusion should be? I am not interested in hinge axis centricity as this is just a theory; I definitely would not depend on an adjustable articulator's findings to determine a balanced occlusion of natural teeth. Consequently, if there is no pathology, I would leave the occlusion alone for the position of each individual tooth is already determined by the forces exerted upon the inclined cuspal planes of that tooth; and it is already better positioned in the alveolar bone to counteract these occlusal forces then we could ever determine by adhering to a questionable ideal. "It seems to me to be precarious through prosthetic reconstruction in persons with some of their teeth present, or through other therapeutic measures, for example, grinding, in patients with teeth present, to cause the mandible's lateral gliding movements to start from its retruded position, as this intermaxillary relation seems to coincide so relatively seldom with the intercuspal position."[30] "If pathology is present, I would determine the interferences in the mouth by observation of facets or by the use of wax."[31] "In grinding the inclined planes to eliminate interferences, I would follow the usual pattern of wear associated with normal dentition. Teeth always wear, when viewed from the frontal plane, in a concave direction on the upper with a corresponding convex plane on the lower, or the lingual cusps of the upper and the buccal cusps of the lower posterior teeth will wear. Therefore, to relieve any demonstrated interferences in the mouth, I would

recommend that the lingual of the upper and the buccal cusps of the lower should be judiciously ground."[32]

From a sagittal view, the distal cuspal inclines of the upper and the mesial inclines of the lower teeth would be the correct surfaces to grind to keep the dentition, in physiologic harmony with the known direction of wear. Teeth always wear in these directions because the mandible and maxilla are anatomic machines to comminute food for ingestion. It is almost axiomatic, in the science of engineering in the study of wear of any machine involving a fixed and a movable member with both rotatory and translatory movements, that the wear will always be concave on the fixed part of the machine and convex on the movable member. The mandible, having both rotatory and translatory movements will wear its teeth, and the opposing fixed maxillary teeth in this pattern. Therefore, it is more scientific to grind teeth to follow this physiologic direction of wear, than to arbitrarily follow the abnormal dictates of movement of the articulator.

The problem of a balanced occlusion for full dentures is different than for natural teeth, because force in functional or nonfunctional movements of the mandible is directed over the entire supporting structures of the dentures, while this same force may be borne by the periodontium of a single tooth in a natural dentition. Also, when setting teeth for full dentures, one can more readily achieve a geometric ideal for occlusion than that, for instance, which may be obtained by grinding a natural dentition. The prime requisite for a balanced occlusion in full denture construction is an accurate centric relation. I use a central bearing screw set to the correct vertical dimension, and moving upon a flat plate. A Gothic arch is traced, and its apex is checked with a plaster checkbite to determine centric relation. I do not record any other eccentric positional relations, such as right or left lateral, because the patient does not normally use these relations in function, and if they were of value, the eccentric positions can be altered by checkbites obtained with a concave or convex plane. The casts are mounted on a rigid plane line articulator with an incisal guide pin without the use of the face-bow. The anterior teeth are selected and arranged for esthetics. Nonanatomic cuspless teeth are used for the posterior occlusion. The posterior occlusal plane which I accept as a geometric ideal is the reverse, anti-Monson or Pleasure curve as viewed from the frontal aspect.[33–36] Thus, the lingual surfaces of the lower posterior teeth are at a higher horizontal level than the buccal cusps. The upper posterior teeth are set to correspond with the lower teeth. The occlusal plane, in a sagittal view, is flat with no compensating curve. Years ago, following the concepts of the leading articulator theories, I obtained a so-called balance in protrusion by using a nonanatomic posterior tooth inserted in the retromolar region of the lower denture to contact the distocclusal surface of the upper molar in protrusion.[37] Since the advent of plastic teeth, and especially the early manufactured ones where occlusal wear could be readily seen, I never observed any wear on this balancing tooth in any practical denture. As it wasn't effecting a balance, I concluded that it wasn't necessary to obtain such a balance for incising movements.

Kelly[38] studied occlusal wear in case histories of 150 denture wearers with plastic teeth set to a spherical occlusion, and found that the dentures wore into

a reverse occlusal curve. I have many dentures with plastic posterior teeth set to a reverse occlusal curve which exhibit occlusal wear but have not altered their original pattern. To me at least, it is scientific to start with an occlusal plan which follows the known pattern of wear, and more important, one which will direct the forces of mastication to aid in the balance and stabilization of the functioning mandibular denture. Jankelson[39] in his prize-winning essay before the Chicago Dental Society concludes that, "The evidence strongly suggests that centric occlusion is the only tooth contact of any significance that occurs during stomatognathic function. Evidence of eccentric tooth balance during eating was not found. There was no evidence that "balance" of teeth in eccentric position is a physiologic necessity, or that lack of eccentric balance is less conducive to masticatory function."

SUMMARY AND CONCLUSION

The present concept of balanced occlusion is based primarily upon geometry and articulator movement. Various groups have set up different geometric ideals as a guide for occlusion of natural and artificial teeth based primarily on the assumption that the instruments used in their studies follow normal mandibular movements. The hinge axis was discussed, and the condyle path was demonstrated to have different degrees of angulation depending upon the method used to obtain checkbites. The central bearing screw attached to the mandible, and moving on different plates attached to the maxilla, such as flat, convex or concave, will give different registrations from which different occlusions could be determined.

The value of the hinge axis and adjustable articulators as aids to obtaining a balanced occlusion were questioned. The importance of centric relation was stressed as the only point in common between functional and nonfunctional movements, and that if centric relation is correctly recorded, most geometric ideals of occlusion will function for the patient. The direction of occlusal forces varies depending upon the plane of projection, but it is never perpendicular in an axial direction to a natural tooth or perpendicular to the occlusal surfaces of a denture.

A method to grind the occlusion of natural teeth to eliminate interferences, and a method to set artificial teeth was described to follow the direction of physiologic wear of natural teeth and to aid in the stabilization of the lower denture.

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A STUDY OF TOOTH CONTACT DURING MASTICATION WITH ARTIFICIAL DENTURES

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CONFLICTING reports have appeared in dental literature in reference to actual tooth contact during masticatory function. Howell and Brudevold,[1] in their measurements of the forces used during mastication with a full denture, calculated the pressure developed on various teeth. They assumed that the teeth were in contact at centric occlusion during mastication. The use of balancing elements, that is, the postmolar ramp as advocated by Doxtater,[2] Sears,[3] and Hardy[4] is predicated on the belief that these elements contact each other during certain of the excursive movements used in chewing food.

Shanahan[5] stated that contact of teeth occurred at the end of the masticating cycle. Jankelson[6] studied several natural and artificial dentitions and obtained evidence indicating that contact does not occur during mastication, but only during the act of swallowing.

Boos[7] indicated that "the muscle forces are directed so as to bring the teeth into contact" during mastication. Hughes[8] was of the opinion that contact is apparent on both working and balancing sides during the chewing cycle. Shaw[9] stated that teeth do not make appreciable contact during the act of mastication, but that contact, if it occurs, will be at the end of the masticatory stroke.

It was the purpose of this investigation to make detailed studies on tooth contact to determine if previous assumptions were valid, and to attempt to clarify previous experimental and subjective evidence, with special reference to full upper and lower dentures.

METHOD

A total of twelve patients with artificial dentures were studied. They ranged in age from 25 to 55 years. Eight of the appliances possessed Vitallium occlusal (Austenal) posterior teeth, three had H Mold acrylic (Austenal) posterior teeth, and one had French's (Universal) posterior teeth. One patient with Vitallium occlusal posterior teeth had a lower bilateral distal extension saddle partial denture occluded against a full upper denture. It must be emphasized that in all patients studied, nonanatomic teeth were used. Dentures were constructed using the methods described by Hardy.[4]

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The first series of tests were run on individuals with Vitallium occlusal posterior teeth, since there was metal-to-metal contact and no problem of rendering the tooth surface conductive to electric current was apparent. Holes were drilled in the plastic adjacent to the inserts. The bare ends of wire were knotted, inserted, and held in place with silver amalgam. This method provided wire-to-cutter contact as well as securing the wire in place (Fig. 1).

Fig. 1.—Vitallium occlusal teeth wired for testing.

Fig. 2.—Acrylic teeth copperplated and wired for testing.

The acrylic and porcelain teeth studied were rendered conductive by copperplating their occlusal surfaces. The Hanau Electroformer Jr. (Model A) was used for plating. A hole was drilled on the buccal surface of the second bicuspid. The wire was knotted, inserted, and secured with silver amalgam. Using the method suggested by Hanau, a coating of copper was obtained in about twenty minutes. The maximum thickness was .004 inch (Fig. 2).

These wires were then connected in series with a 1½ volt dry battery, and a 0-5 Esterline-Angus graphic ammeter Model AW. A resistance unit was shunted across the battery terminals to reduce the current passing through the entire system. As set up, the apparatus constituted a simple make-and-break circuit. Each contact was recorded as a deflection of a pen line on a moving strip of paper. Fig. 3 shows the detail of the experimental apparatus.

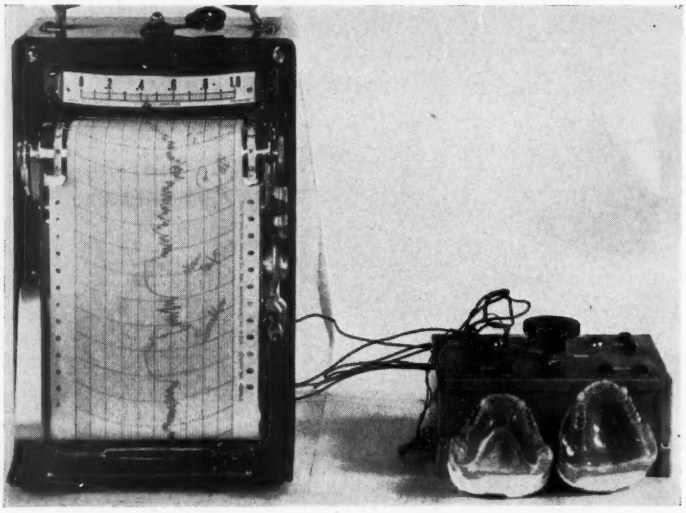

Fig. 3.—Experimental apparatus showing dentures, control box, and recorder.

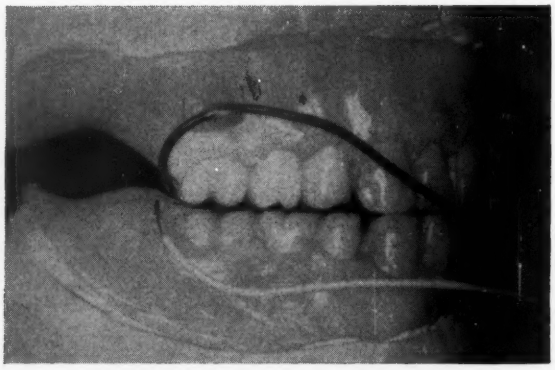

Fig. 4.—Postmolar ramps wired for testing.

Current leakage through the bolus of food and saliva could produce artifacts in the recording device. This possibility was precluded by the introduction of a cathode ray oscilloscope into the circuit. When actual contact occurred a square wave was seen on the screen of the oscilloscope. Current leakage resulted in a gradually ascending wave, or one of lower amplitude. No current leakage was observed during the test period.

During the experimental procedure only one side of the dentures was wired. In all cases this was the side preferred as stated by the subject. By instructing

the subject to chew alternately on right or left sides, both working and balancing contact could be studied with the minimum of electrical attachments. The lead wires were luted to the buccal and labial surfaces of the dentures to assure minimum interference during mastication.

Study of the balancing elements was accomplished by replacing the distal surface of the upper first molar and the "ramp" surface with amalgam, in which lead wires were embedded. Adjustment was then made until contact occurred in lateral excursion, but not in centric occlusion. No conduction occurred between the metal cutters and the amalgam in these cases (Fig. 4).

The subjects were seated in a semiprivate room in such a manner that the deflection of the recording pen was not visible. No instructions were given to the subjects regarding size of bolus chewed, or character of stroke used during the initial phases of the investigation.

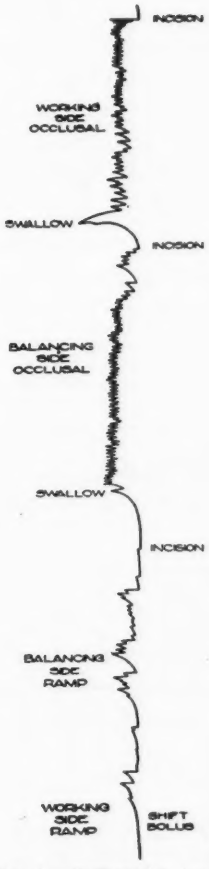

Fig. 5.—Composite tracing.

The test food utilized during this investigation consisted of a corned beef sandwich on dark rye bread. During the course of testing, the character of the bolus was recorded, that is, "centersection," "with crusts," etc. Toasted white bread was also employed. The results presented in Table I include only the former test food.

TABLE I

PATIENT NUMBER	POSTERIOR TEETH	TYPE OF STROKE	APPROXIMATE PER CENT OF CONTACT (5% ERROR)				SWALLOWING CONTACT	COMMENTS
			WORKING SIDE %	BALANCING SIDE %	RAMP			
					WORKING SIDE %	BALANC. SIDE %		
1	Vitallium occlusal	Normal	70	80			+	
2								
Test a	Vitallium occlusal	Normal	100	100			+	Received teeth just before first test, had never worn dentures before
b	Vitallium occlusal	Normal	60–90	100			+	
c	Vitallium occlusal	Light Heavy	0–10 50	100			+	
3								
Test a	Vitallium occlusal	Normal	25–50	100			+	
b	Vitallium occlusal	Normal	30	100	0	20	+	
4	Vitallium occlusal	Normal	100	100	0	25–30	+	
5	Vitallium occlusal	Normal	100	100			+	
6	Vitallium occlusal	Normal	80–100	80–100			+	
7	Vitallium occlusal	Normal	0–5	100			+	Feeble chewer
8								
Test a	Vitallium occlusal	Normal	80	100			+	Full upper, partial lower; had received teeth only a few days before first test
b	Vitallium occlusal	Normal Heavy Light	1 70 1	100				
9	H mold (acrylic)	Normal	90	100			+	
10	H mold (acrylic)	Normal Light	90 45	50			+	
11	H mold (acrylic)	Normal	20–100	100			+	Very great inter. a trial variation; had recently received teeth
12	French's posteriors				0	100		Tested for ramp function only

The amount of contact was evaluated as the percentage of strokes that contacted while the bolus was being masticated. The total number of strokes was counted from the time of incision to swallowing.

RESULTS

The results are presented in Table I. Fig. 5 is a composite tracing of the contacts that occurred while one subject ate a corned beef sandwich. Eight of the patients showed contact more than 70 per cent of the time on the working side. Two of these (No. 2 and No. 8) showed a decrease in percentage of contact on subsequent trials. The two patients with all acrylic posteriors showed approximately 90 per cent contact on the working side.

Subjects showing decreased or variable contact on repeated tests were instructed to chew with light, normal, and then heavy pressure. The percentage of contact with normal pressure was the same as at light pressure, but it increased sharply with heavy chewing. Patient No. 10, who had a normal stroke contact of 90 per cent was instructed to chew lightly; his contact dropped to 45 per cent. All patients except one approximated 100 per cent contact on the balancing side.

Three subjects were tested for ramp function. Two averaged 25 per cent contact. The ramps appeared to have sharply defined periods of contact; the first contact occurring just after incision was of the greatest duration, and each subsequent contact thereafter was of lesser duration. Patient No. 12 gave continuous ramp contact throughout the chewing process. A gradual decrease in contact duration was noted as chewing progressed. No contact between the lower ramp and the upper first molar was evidenced on the working side.

All patients showed contact during swallowing. Due to the simplicity of the experimental apparatus, it was felt by the investigators that an error of approximately 5 per cent was present, even though the data indicated greater accuracy.

CONCLUSION AND SUMMARY

Tooth contact during mastication has been studied in twelve denture wearers. All exhibited contact on the working side during mastication although the percentage of contact varied from patient to patient and from trial to trial. Teeth on the balancing side approximately 100 per cent contact.

Contact between the postmolar ramp of the lower denture and the distal edge of the upper first molar occurred on the balancing side in all three subjects studied. The type of contact indicated that the function of the ramp was greatest when the bolus of food was large and decreased as penetration and comminution progressed.

The authors wish to acknowledge the consultant services afforded by Dr. I. R. Hardy during the course of this investigation.

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THE MECHANICS OF THE CHEWING MOVEMENTS OF THE HUMAN JAW*

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THE CHEWING movement of the mandible is a combination of two movements, opening and closing, in which the mandible moves as a ginglymus joint about a transverse axis passing through the glenoid fossae, and a milling movement in which the mandible moves horizontally, alternating about vertical axes in right and left temporomandibular joints. A third movement consists in a protrusive and retrusive simultaneous gliding of the two heads of the condyles in which the mandible is carried likewise forward and backward.

Of these three, the milling movement has until now received the least investigation, although it, with its hinge movement, is practically the most important for the act of chewing.

What is known about it is supported by the knowledge of the structure of the temporomandibular joint, and by observations of the excursions of the mandible in skeletons and in living human beings.

The above description almost covers the matter, yet the most important point of the question remained unanswered: What path is described by the lower occlusal surfaces against the upper ones?

True, plastic material has been inserted between the opposing occlusal surfaces in an attempt to find the explanation, but this has met with no success because by this method the paths of individual points cannot be determined. Nevertheless, I thank the failure of this method for the hint that led to the desired goal. Instead of allowing all points of the occlusal areas to trace their courses simultaneously, it was necessary to try tracing the courses of single points.

I achieved this by experiments with patients who had cavities in their lower teeth. A graphite stylus was inserted perpendicularly in the cavity, the point of which ended at the level of occlusal surfaces of the two neighboring teeth. The fixing of the graphite stylus was done by putting it into a metal tube fastened to the two neighboring teeth with two metal rings. This graphite stylus now presented a definite point of the occlusal area of the tooth that previously occupied the space, and this point scribes its course on the occlusal surface of the upper arch during lateral jaw movement. Since the tooth enamel takes the graphite poorly,

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†Deceased.

the upper tooth surface should be covered with adhesive tape or with a small tracing plate made of hard rubber.*

Even the first attempt yielded unexpected results. Using the space of a lower first molar, a tracing was made on the upper occlusal surface from the lingual to the buccal surface of the crown. It was evident that only part of the movement was recorded and I surmised that the remaining part had not been scribed because the mandible carrying the graphite stylus was too far from the upper surface during part of the lateral movement. I improved the device by placing a coil spring at the base of the metal tube under the graphite stylus. Thus the continuous contact of the graphite with the upper occlusal surface was assured, and then a second line appeared which ran to the anterior part of the arch with a slight median deviation toward the anterior end. Both lines have the same starting point.

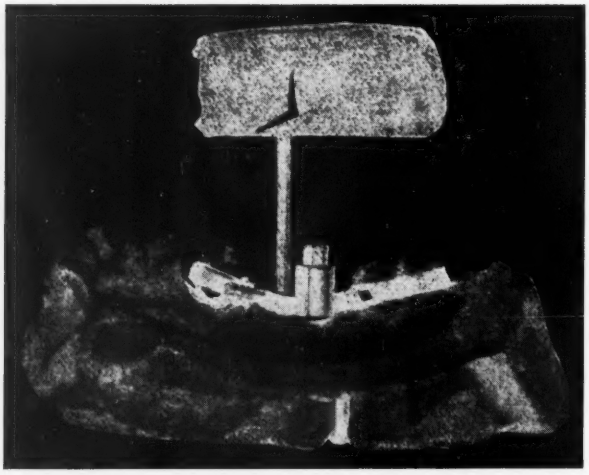

Fig 1.—The lower cast united with its attached tracing device together with the tracing made in the mouth. The graph plate standing above the cast has been twisted outwardly at right angle to turn it toward the eye of the observer.

The complete pattern of the tracings is an obtuse angle whose apex points lingually, whose posterior transverse path crosses the occlusal surface, and whose sagittal path runs forwardly and inwardly (Fig. 1).

It is clear that the two arcs belong each to a different part of the chewing movement. The transverse arc is scribed when the condyle head of the same side constitutes the center; the sagittal arc is scribed when the condyle head of the opposite side constitutes the center.

In this manner, the most important question is answered. Each point of the mandible has its still point on the upper occlusal surface, the contact point during closure, with no lateral jaw movement. The condyle heads remain in their sockets.

*The placing of the graph plate provides the part of the upper jaw. Its adaptation to the teeth is made easier, and its attachment is improved when that part of the graph plate lying directly against the teeth is made of soft rubber, only the outer shell being of hard rubber.

While chewing, each of these points moves transversely out and back when the corresponding condyle remains against its stop, each point scribing an arc around the joint of the same side. If the condyle head of only one side leaves its stop, then each point of the same side traces a sagittal path in a forward and inward direction (and back in the same path), each point scribing an arc around the joint of the opposite side.

The farther the points from the temporomandibular joint, the more obtuse is the angle enclosed by the transverse and sagittal paths.

With the knowledge thus acquired, two experiments will be made to amplify and confirm this deduction. First, let us imitate the chewing movement on a skull, observing only the path of the lower right first molar. So long as the right condyle remains in its socket, the tooth scribes a clear path buccally and back to its starting point. A part of the lower right occlusal surface travels over the upper buccal area of its antagonist, without, however, changing its anteroposterior relation. Then if the same condyle head be allowed to glide on the articular eminence, this changes the lateral relation of the opposing occlusal areas very little, but it does produce a marked change in the sagittal direction. The lower tooth moves anteriorly and can reach the position previously occupied by its neighbor to the front.

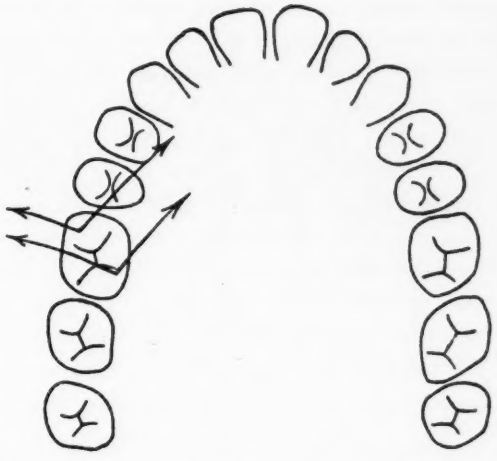

Fig. 2.—Schematic representation of the circular paths of two mandibular points.

The second experiment is made with a compass on a skull whose mandible has been removed. One leg of the compass is set in the center of the glenoid fossa and the other leg at any desired point on the occlusal surface of the same side. The arc gives the path scribed by the corresponding mandibular point when the joint of the same side contains the vertical axis. It runs transversely. Then one leg of the compass is placed in the center of the opposite glenoid fossa with the other leg at the previously chosen occlusal point, thus obtaining a different arc running somewhat sagittally. It represents the path of the lower molar point when the vertical axis lies in the socket of the opposite side. For the movements of the mandible the only consideration is the point of intersection of both arcs.

Perhaps according to these experiments we are not yet justified in assuming any definite efficiency in chewing since this has been considered only incidentally.

The descent of the mandible whose condyle heads move onto the articular eminence causes the sagittal path of the chewing movement to work less efficiently, because in this movement the antagonists do not touch each other, whereas the lateral movement scribes a path in which the lower masticating area remains continually in contact with the upper one. In view of the range which both tooth arches can travel in chewing, I hold that individual deviations are very likely. The usual region where the separation reaches its greatest height is the lower first molar, together with the distal part of the second bicuspid; contact is made in the region of the seventh and eighth teeth even as the condyles are protruded while the occlusal arch is separated toward the distal surface of the wisdom tooth. While moderate right and left movements cause each mandibular point to scribe two intersecting arcs, it is possible to bring about slight variations with forced movements. This means that a small surface is being traced. However, the tracing stylus never passes outside the enclosed angle. One can hardly go wrong in assuming that the point has sufficient looseness to allow slight anterior dislocations of the condyle heads.*

The results of these studies afford an immediate application to an important phase of our professional work, the setting of teeth for artificial dentures. Such dentures can be useful in chewing only if they permit the essential jaw movement laterally without interference, and without occlusal separation. For this reason, articulators that permit only hinge movements appear useless since they do not provide for lateral movements. Bonwill's articulator overcame this difficulty long ago, and as it is favorably located in the center of the human jaw, it puts us in position to create a really efficient artificial tooth. Whoever takes the trouble to repeat these experiments with mandibular movements on an articulator as presented in Bonwill's essay will be convinced that these movements take place as we have learned from the bite. The only thing that Bonwill's articulator does not give is the descent of the half of the mandible as it moves on the articular eminence. But this defect is unimportant for the making of artificial restorations, since, in the mouth, this part of the movement is attained during mastication.

*With these experiments it is not difficult to imagine the movements that must occur in the joint. In the whole experiment, the mandible represents an apparatus that we would first need to create if we were presented with the problem of observing the movements of the condyle in the joint, the mandible being a rigid lever whose back end is fastened at the temporomandibular joint and whose front end reproduces in magnified form the excursions of the condyles.

ACCURATE TRACINGS OF MANDIBULAR MOVEMENTS

GEORGE WOOD CLAPP, D.D.S.

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CHICK[1] TELLS us he has checked the tracings of mandibular movements Gysi has given us, and expresses his opinions as follows (J. PROS. DEN. **3**:467-473, July, 1953): "It is unnecessary to repeat Gysi's work to find that these tracings are inaccurate. All that need be done is to mark on a piece of tracing paper the starting positions of each point of reference. . . . If, therefore, the tracing paper is moved so that any two of our marks lie above the appropriate points, we should expect all the others to do likewise. It is immediately found, however, that they do not . . . some of the errors are relatively enormous. . . . The great majority of articles on prosthetic dentistry are no more than expressions of opinion without factual backing of any sort, yet they are frequently quoted as authoritative."

WHAT PROMPTED GYSI'S EFFORT AND TRACINGS

Bennett had recorded the movements of the mandible by illuminations and calculations which are not practicable to dentists generally. It was doubtful whether a practicable articulator could make use of them. Gysi, as Professor of Prosthetic Dentistry, University of Zurich, and his assistants, gave two weeks of continuous labor to confirming Bennett's discoveries and to devising methods by which jaw movements could be recorded in procedures all dentists could use.

THE MANNER OF THE GYSI EFFORT

Gysi found that he was excellent demonstration material for their study. He had lost some of his lower posterior teeth on each side of the jaw. All of his other teeth remained and were in perfect condition and articulation. He made a partial plate that fitted the endentulous spaces and could be clamped firmly in place by means of bands around adjoining teeth. Stiff wires were brought around the buccal surfaces of the natural teeth from both sides to the median line. Here they were soldered together and passed out between the lips. The wires for making tracings were continued to three points: to the midline of the chin, and to locations over the center of each condyle. The end of each wire was fitted to hold a tiny pencil (Fig. 1). Later, wires were extended to other points of interest.[2]

A horizontal plane, representing the occlusal plane, was affixed to the wires to facilitate more accurate record-taking than might be possible without it. The entire appliance was stable in position and made all the movements the jaw made.

In Fig. 2, the pencils at the condyles were turned upward so that they registered on plates of ground glass which were held firmly in position. The mandible was

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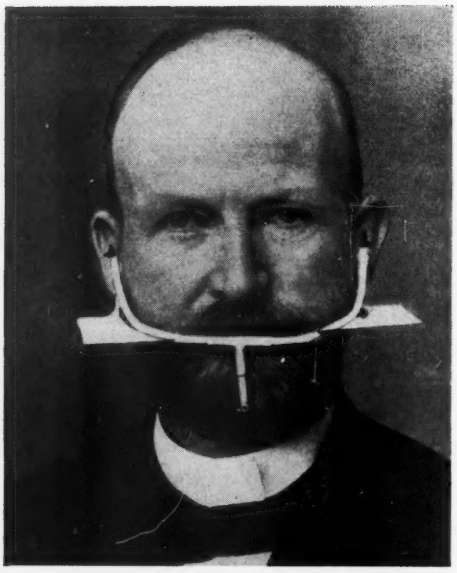

Fig. 1.—The tracing equipment. (From Prosthetic Articulation, Fig. 91).

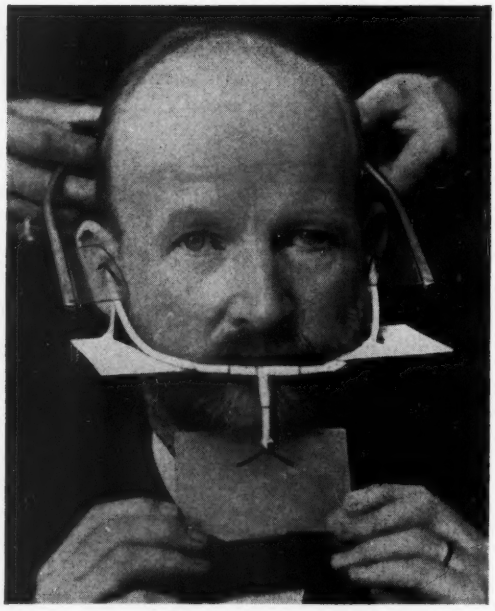

Fig. 2.—Recording lateral movements of the condyles and chin. (From Prosthetic Articulation, Fig. 98.)

moved laterally in both directions. The pencils recorded an inward inclination of 16 degrees in each advancing condyle path. This inclination had never been known before.*

Below the chin, a card was held firmly at right angles to the sagittal plane. The record of the lateral movements is shown.

Out of these studies came the Gothic arch tracing procedure for the recording of lateral centric relation. It is in constant use throughout the dental profession and has never been criticized as a merely personal opinion.

There were no known recordings of the opening and closing movements. It was important that there should be such recordings, and that they should be understandable and usable. The closing movements are important in the articulation of artificial teeth.

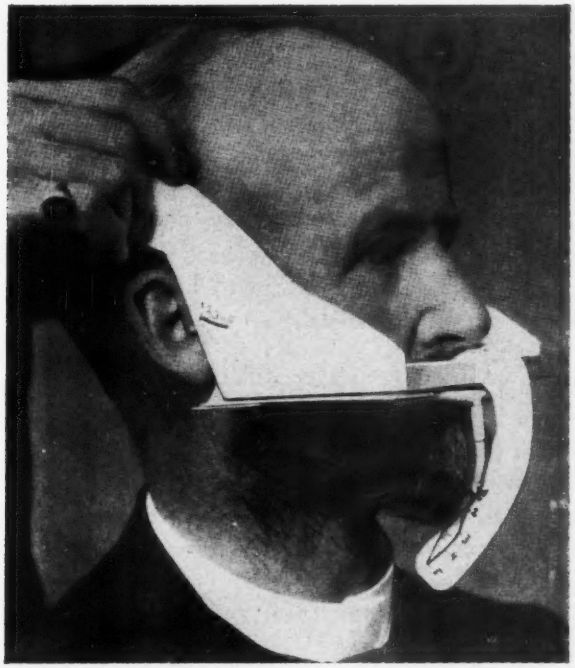

Fig. 3.—Recording straight opening and closing movements. This figure is slightly enlarged so that the tracing at the chin may be clearly visible while we study it. (From Prosthetic Articulation, Fig. 92.)

A frame like the one shown in Fig. 3 was based on the occlusal plane shown in Fig. 1. It was held firmly against the head while the movements were made. In Fig. 3, the pencils that made the tracings at the right condyle and the chin have been taken away to permit clearer vision of the tracings they had made.

The tracing at the chin is especially important to us because it shows what seems to be proof of the accuracy of the tracings.

The chin is the point of the mandible that is farthest away from the condyles. If there are errors in recording opening and closing movements, they should show

*This inclination has recently been confirmed by extensive professional investigation and recordings.

here. If the tracings are demonstrably correct at the chin, the tracings at the other points should be acceptable.

We see first that this tracing of the complete opening and closing movement is not a single line, as the other tracings are. It is made up of two unlike lines. In the opening movement, the pencil traced the outer line which is numbered in stations. In the closing movement, it traced a very different line. There is no wavering or confusion in either line. The pencil did not cross from one line to the other. It started at occlusion and went down to a definite point at extreme opening. In closing, it left that point at once and made a very different tracing almost up to closing. It stayed on the path of each movement until movement ceased.

Gysi wanted to be certain of this record and tested it thoroughly. He found he could open and close his mouth as often as he wished, rapidly or slowly. The pencil followed the same lines each time and returned to the same point.

Why were there two paths? There were two separate paths because there were two movements, activated by two different groups of muscles. The mandible was pulled down by the inframandibular muscles. It was pulled upward by the supramandibular muscles. The external pterygoid muscles had no influence on either of these movements. When both of the external pterygoid muscles have been separated from the mandible by surgery, the patient can perform the straight opening and closing jaw movements just as he did before.

Fig. 3 shows that, at the point farthest away from the condyles, on the mandible, and at the end of the most extended movement that point can make, the tracing is unwavering and exact.

When the two most widely separated points in a solid body are moved in definite paths, intermediate points here and there in that body cannot have independent and divergent paths. The movements of the body, as a whole, determine the paths for all intermediate points, and the paths must follow them. That is what has occurred as these tracings were made.

The tracings are far removed from merely personal opinions.

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CUSPAL COORDINATION

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MY PURPOSE in writing this article is to present certain improved methods and instruments which will make for further accuracy in the restoration of an impaired masticatory apparatus to cuspal coordination.

You are familiar with the procedure of opening the vertical dimension in the reconstruction of natural dentures. This method necessitates making one or two inlays to hold the vertical dimension open at the desired distance. The remaining teeth are then restored with inlays, crowns, or bridges.

I will describe a procedure which is distinctly different. The fundamentals of this procedure were suggested some years ago by Dr. Frank Wadsworth. While I was taking his prosthetic course in January, 1924, he told how the natural denture could be rebuilt outside the mouth on his articulator. This is done by placing amalgam dies in plaster casts, and surveying the casts for the purpose of restoring cuspal alignment in relation to the curve of Spee.

From the early instruction I received in his prosthetic course, I could readily see the value of balancing teeth when rebuilding a natural denture. After constructing a few of them, I realized, however, that certain procedures must be improved upon to obtain the results necessary for an efficient masticating apparatus.

This type of prosthetic restoration is built outside the mouth, on a mechanical device which is used to imitate the natural movements of the mandible. The reproduction of these movements on the articulator presents one of our greatest problems.

COMPLEXITIES OF MANDIBULAR MOVEMENTS

The temporomandibular articulation is a complicated joint by reason of its many variations in movement. The condyle moves in the fossa on a cushion, is suspended by ligaments, and propelled by muscles. During the lateral excursion of the mandible, one condyle pivots in its glenoid fossa, and the opposite condyle glides forward, downward, and inward. Simultaneously, the mandible moves sidewise bodily; this motion is called the lateral side shift. As the jaw opens and closes in its initial opening, it moves in an arc about an axis of the joint[1,2,4] (Fig. 4).

Complexities are further increased by the two joints being asymmetric. The fossa may vary in depth and the condyle paths may vary in their degree of in-

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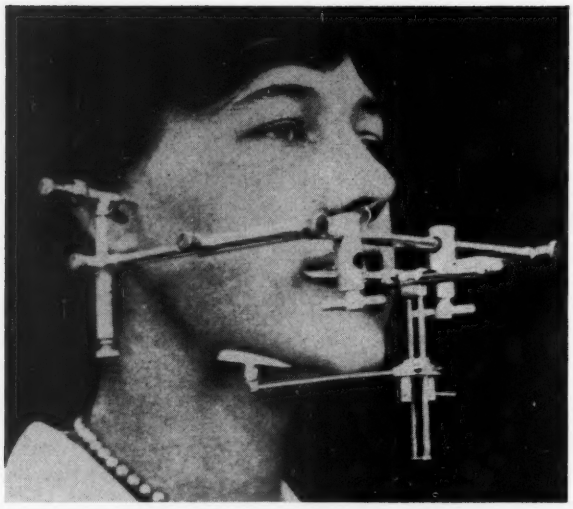

Fig. 1.—The mandibular adaptable clamp and adjustable face-bow in position for locating the hinge-axis of the temporomandibular articulation.

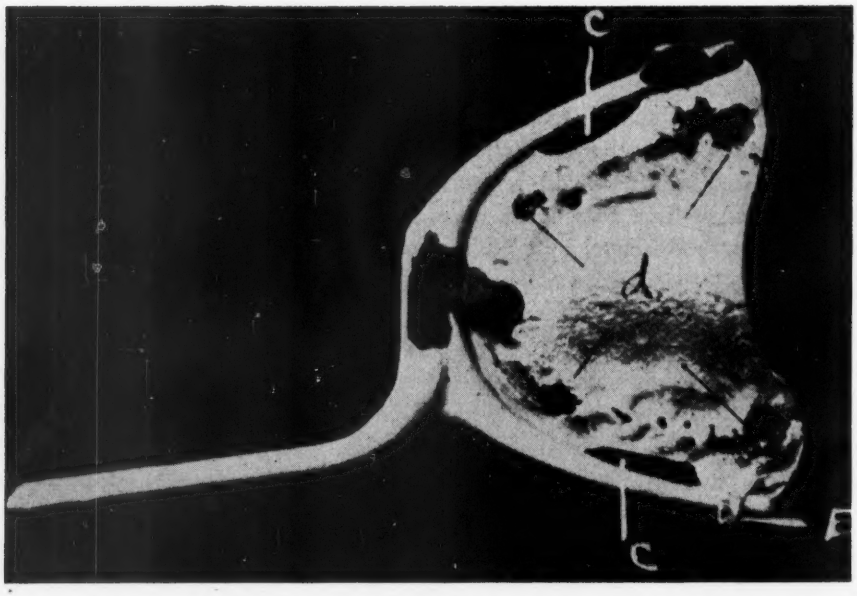

Fig. 2.—Aluminum bite-block and aluminum bite-fork. *c*, Openings for the hook of the adjustable yoke of the clamp. *d*, Compound is placed in the cuspid and molar regions of the bite-block to equalize pressure in four points. *E*, a loop in the bite-block is provided for anchorage when locking the fork to the bite-block with compound.

clination thus presenting different characteristics on each side. The condyle may be larger, longer, or thicker, and the neck of the condyle may be out of proportion to its fellow of the opposite side.

THE TRANSFER

Since there are so many complexities in the temporomandibular articulation, you will readily appreciate the necessity for accurate instruments and methods when transferring the casts to the articulator and imitating the natural movements of the mandible.

The transfer is the orientation of the two casts in the articulator to the same relationship which exists between the dental arches and the hinge-axis of the patient. In making this transfer, the hinge-axis is located definitely with an adjustable face-bow (Fig. 1). This is accomplished by first locking an occlusion rim and bite-fork (Fig. 2) firmly to the mandible with an adaptable clamp (Figs. 3 and 5). This was designed to simplify the technique and render it more accurate. The face-bow is then fastened to the fork, and the hinge-axis is located by slightly opening and closing the mandible, and by moving the condyle indicator about the temporomandibular joint until it pivots over a definite point (Fig. 1).

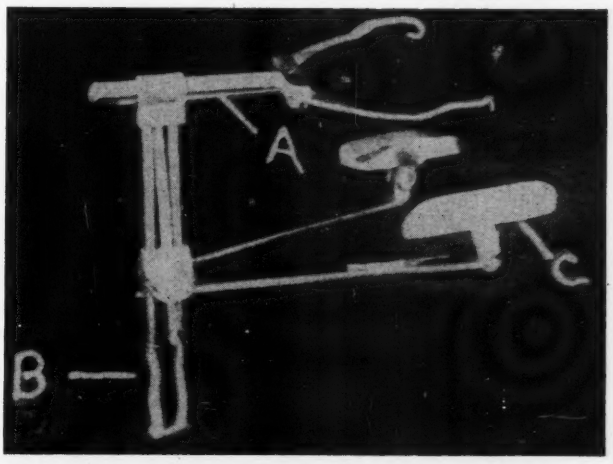

Fig. 3.—The adaptable clamp which is used to hold the bite-block firmly to the mandible. *A*, The adjustable yoke which is provided with hooks to rest on the bite-fork. *B*, Posts which guide the clamp when opening. They also function as binding posts and lock the clamp after the instrument has been adjusted to the mandible. *C*, Saddles which are mounted on a universal joint, making it possible to fit any mandible.

No doubt you have had the difficulty of definitely placing the condyle indicators of the Snow face-bow over the joint, and then losing the correct position by tightening the toggle clamp. This was very apparent when I was shown the technique of locating the hinge-axis with the aid of the Snow face-bow. At that time I recognized the necessity for simplifying the apparently difficult technique, and for making the procedure more accurate. So I suggested to my preceptors a change in the face-bow which would permit the moving of one condyle indicator at a time, without loosening the toggle clamp.

Fig. 4

Fig. 5.

Fig. 6.

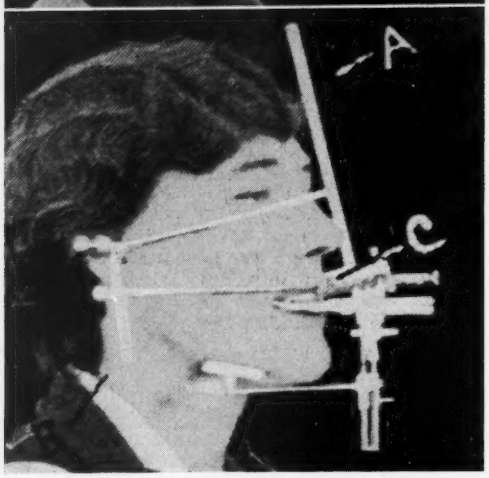

Fig. 4.—The mandible moves in an arc in its initial opening.

Fig. 5.—The adaptable clamp holding the bite-block and fork to the mandible.

Fig. 6.—*A*, The Wadsworth T attached to the face-bow. It is used to relate the cast on the articulator in the same horizontal and perpendicular planes which the dental arches maintain in the mouth. *A*, The jack screw which controls the perpendicular movement of axis-indicator. *C*, The jack screw which controls the horizontal movement of the axis-indicator. *x*, The axis-indicator.

Shortly after making an experimental adjustable face-bow, I discovered that other men[1,3] had face-bows which allowed for the unilateral movement, but none of these instruments, in my opinion, permits the precise adjustments which facilitate the location of the hinge-axis.

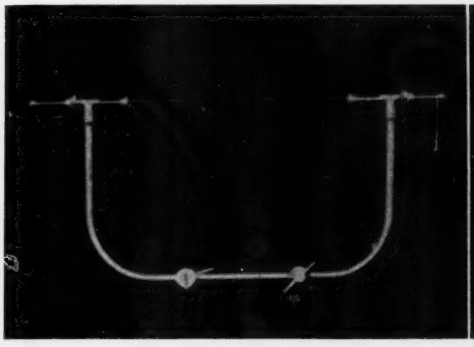

Fig. 7.

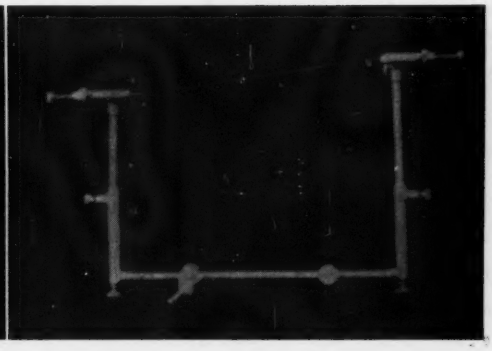

Fig. 8.

Fig. 7.—The Snow face-bow showing the axis between the two condyle pins. These pins, which are opposite to each other on the same plane, can be moved in or out to fit the articulator without destroying a transfer.

Fig. 8.—The adjustable face-bow showing the axis-indicators on a different plane. If these indicators were moved in, they would not travel along a common axis.

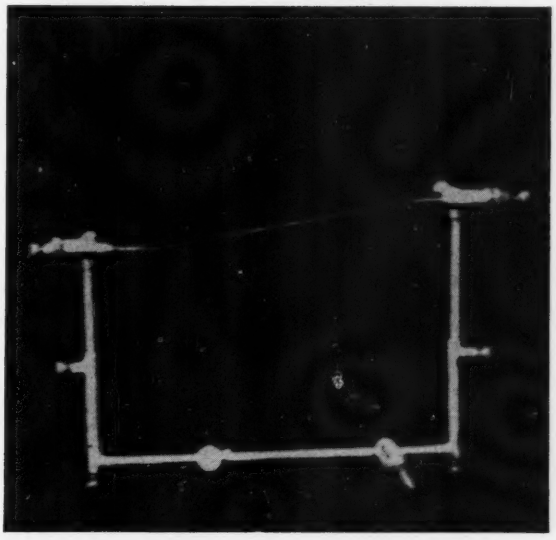

Fig. 9.—The axis-indicators moved in. The distance between the two cords indicates a possible discrepancy in changing the indicators.

The axis-indicator of each side of the adjustable face-bow is moved in three directions to make definite measurements (Fig. 6). The axis pin (Fig. 6, *X*) is moved to and from the face while the horizontal and perpendicular movements are controlled by jack screws (Fig. 6, *B* and *C*). To stabilize the instrument while mounting the casts on the articulator, the occlusion rim and axis indicators are tied together with braces (Fig. 10, *H*).

This type of face-bow has brought about another problem while mounting the casts on the articulator. The axis-indicators cannot be changed. The condyle pins of the Snow face-bow (Fig. 7) are opposite each other on the same plane, and they can be moved in or out to fit the articulator without destroying the transfer.

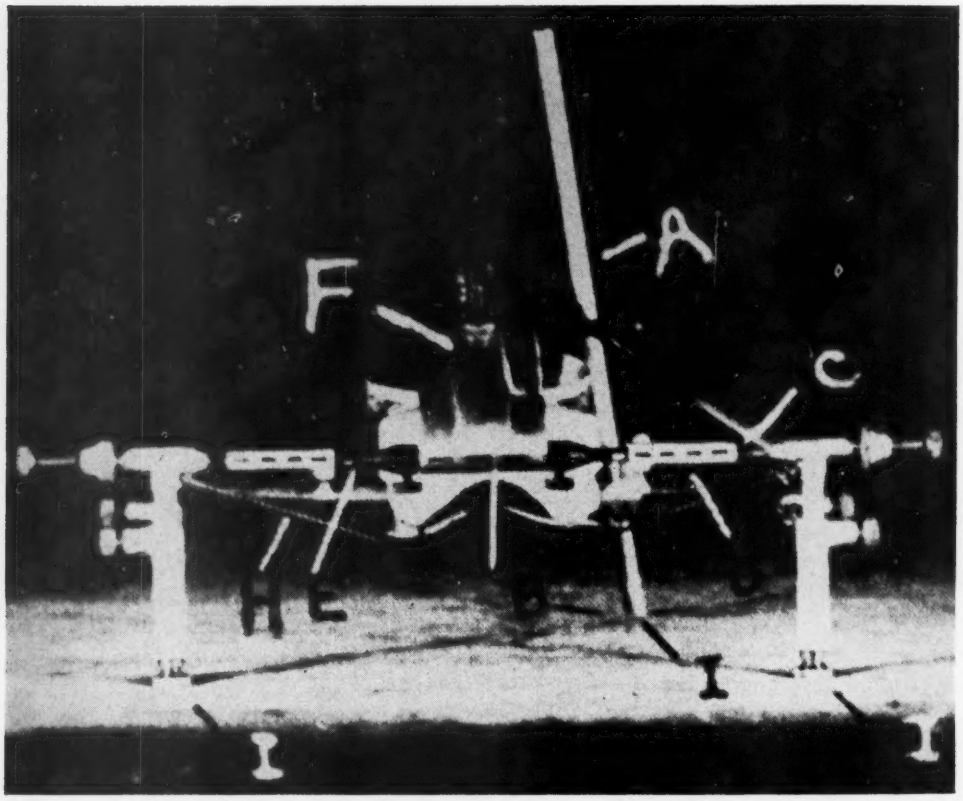

Fig. 10.—(Rear View.) The articulator is made adjustable to fit the face-bow. The maxillary cast is attached to the (*F*) upper arm of the articulator—off the articulator—for simplicity and accuracy. The face-bow is fastened to the shaft by two (*D*) sleeve devices which can be moved in or out to take care of the measurement provided by the face-bow. *B* represents the dotted line as the hinge-axis which is transferred to the center of the shaft and extends between the two indicators; *C*, the ball and socket attachment; *A*, the Wadsworth T. The casts (*E*) are centered on the instrument by means of callibrations on the shaft. The wire braces (*H*) which tie the axis-indicator and bite-block together. The tripod (*I*) provided by face-bow and Wadsworth T.

This is not true with the adjustable face-bow. The axis-indicators transfer the hinge-axis which extends between the two pins (Fig. 8). These two indicators never form a straight line and are never opposite each other on the same plane, and if moved in or out, they would not travel along a common axis and would destroy an accurate transfer (Fig. 9).

To overcome this problem, the articulator should be made adjustable to fit the face-bow (Fig. 10). This change can be made on any articulator, but on this instrument, the McCollum Gnathograph, the upper arm is removed from the articulator, and also, the two ends of the shaft are removed to permit the mounting of casts of patients with narrow faces. The face-bow is fastened to the shaft by two sleeve devices (Fig. 10, *D*), and at the same time, the casts are centered by means of calibrations (Fig. 10, *E*) on the shaft. These sleeves, which fit over each end of

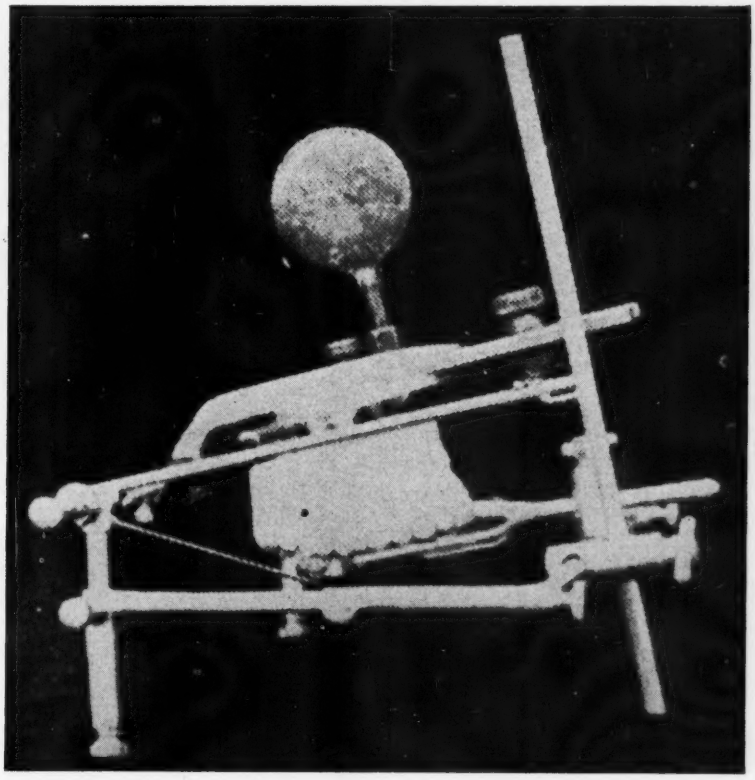

Fig. 11.—The upper arm of the articulator is placed parallel to the Wadsworth T to establish the maxillary cast to the same horizontal and perpendicular planes which the dental arches maintain in the mouth.

the shaft, are provided with a socket to receive the ball (Fig. 10, *C*) of the axis-indicators, thereby connecting the face-bow to the upper portion of the articulator. To mount the maxillary cast in the proper relation to the horizontal plane, the upper bow of the articulator is placed parallel to the Wadsworth T (Fig. 11). At the completion of the maxillary mounting, the upper arm is placed back in the articulator, and the lower cast is mounted by means of a centric checkbite.

IMITATION OF MANDIBULAR MOVEMENTS

There are many ways of imitating the natural movements of the jaw. I am going to deal with the wax checkbite method, because it is the method by which I am able to obtain satisfactory results.

The centric relationship of the casts on the articulator is obtained with a wax checkbite. It is the key to balancing the occlusal surfaces of teeth. A failure to obtain equal pressure between the two arches will not only unbalance centric occlusion, but render it impossible to balance the occlusion in the various lateral and protrusive movements. The centric relation should be recorded when the condyles are placed posteriorly and seated in the glenoid fossae. By doing this, the condyles will be placed in the same position that existed when the hinge-axis was located (Fig. 12). A centric wax checkbite, made in this particular jaw relationship, makes it possible to open the vertical dimension on the articulator, and follow the same path of opening which exists in the mouth.

Fig. 13.

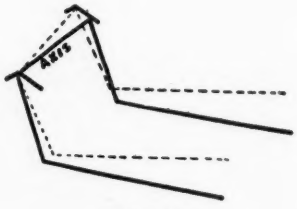

Fig. 12.

Fig. 12.—The relation of the mandible to the glenoid fossa when the centric checkbite is made. The condyle heads are placed posteriorly on the condyle paths. The hinge-axis is located when the condyles are in this same position.

Fig. 13.—The relation of one condyle to the glenoid fossa when the lateral checkbite is made. The pivoting condyle is placed most posteriorly on the condyle path while the opposite condyle is down on the path.

The lateral checkbite is obtained by a wax impression of the upper and lower teeth while the mandible is in the lateral relationship. This should be accomplished when the pivoting condyle is placed posteriorly and seated in the glenoid fossa (Fig. 13). By obtaining the arch relations with the centric and two lateral checkbites in the manner just stated, and by setting the articulator to duplicate the same relations between the casts, the opening or closing and the right or left lateral movements of the mandible will pass through the arcs about the axis that exists in the mouth, thus imitating the natural movements of the mandible.

CONSTRUCTION OF THE RESTORATIONS

After setting the articulator to follow the natural movements of the mandible, a definite procedure is followed in building the restorations. In the construction of such extensive restoration (Figs. 14 and 15), all the teeth to be restored should be built in wax to a cuspal coordination to provide a pattern of the castings to be constructed (Figs. 16, 17, 18, and 19).

This degree of wax tooth coordination came to my mind after completing a full-mouth restoration on a Wadsworth articulator. Dissatisfied with the protrusive balance of the occlusion, I procured another articulator which established the inclination of the protrusive movement by the incisal guide plate (Fig. 17, *A*).

This protrusive guidance proved its worth while I was constructing the restorations for the next patient. It was possible, with the aid of the lateral incisal guide plate of the articulator, to shape wax teeth which would move across each other in harmony in any direction, an achievement which I had not done before with any degree of accuracy.

Since the teeth are of a plastic material, it is possible to establish the contour, position, and alignment which will best imitate nature (Figs. 18 and 19). Also, the cusps and their flat planes of the wax teeth may be readily rearranged to establish the best tooth form (Fig. 18) and normal relationship (Fig. 17), and yet have anatomic balance when the case affords that possibility.

In addition to being practical, this procedure of modeling the teeth in wax to a cuspal balance has an instructive value. It has taught me many of the functional principles of the occlusal surfaces of the teeth and has revealed to me a great deal of nature's architectural plan of the masticating mechanism, as I had never before comprehended.

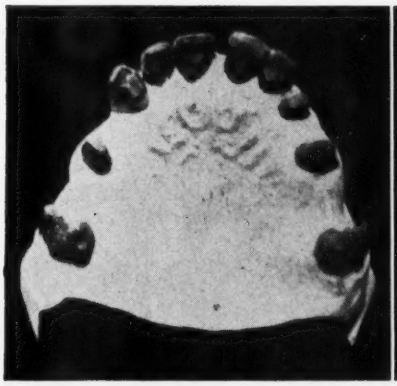

Fig. 14.

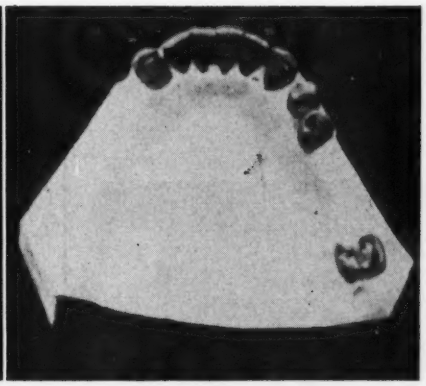

Fig. 15.

Fig. 14.—The mandibular cast of a case which is to be restored with a removable partial denture.

Fig. 15.—The maxillary cast of a case which is to be restored with fixed bridges.

Shortly after discovering what could be done with wax modeling I took an extension course given under the auspices of the Southern California Dental Association to acquaint myself with other methods of restorative dentistry. It was there that wax modeling was introduced and again proved its instructive worth. When the point of constructing the restorations was reached, I demonstrated a means of duplicating these wax teeth in gold or porcelain without losing the balance which was established.

To convert the wax into permanent restorations proves to be a problem when opposing bridges are to be made. The inclinations of the planes established in wax are retained by casting each tooth of one entire unit of metal (Fig. 20). The abutment inlays are cast of gold, while the wax teeth in the bridge spaces are cast of a low-fusing metal. A hard surface is thus provided to which the opposing porcelain teeth may be spot-ground. This is of particular value when the porcelain

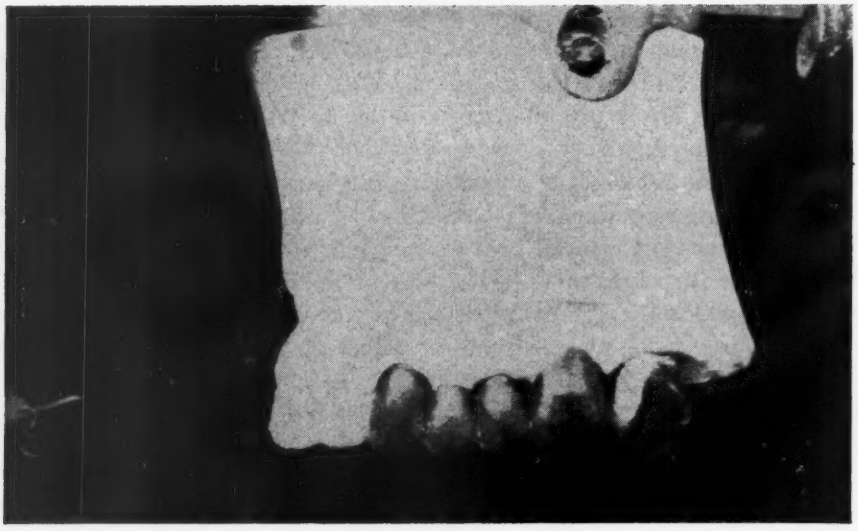

Fig. 16.—The maxillary teeth are shaped into tooth form and placed on Wadsworth's basic curve which represents the curve of Spee.

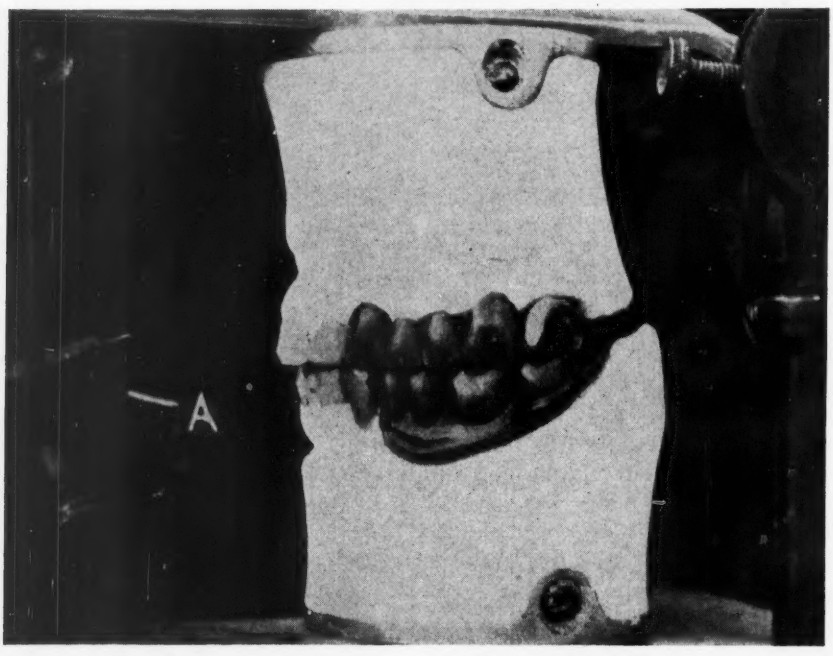

Fig. 17.—The maxillary and mandibular restorations modeled in wax to provide a pattern of the restorations to be constructed. *A*, incisal guide plate with the inclination which establishes the planes on the wax teeth in the protrusive movement. Note: The normal relation of upper and lower first and second molars.

teeth of a removable partial denture are ground in. It also facilitates grinding-in long-pin facings when a minimum amount of gold is desired for esthetic reasons. After replacing the wax with the permanent restorations, the cusps and their planes should oppose each other as in the wax pattern.

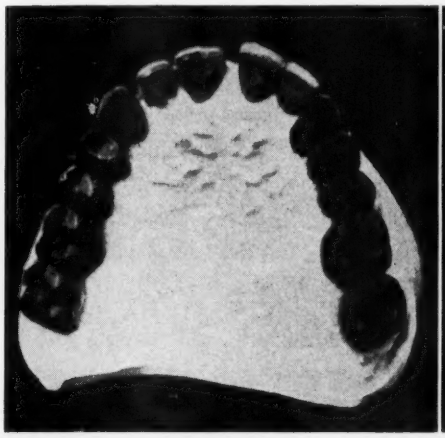

Fig. 18.

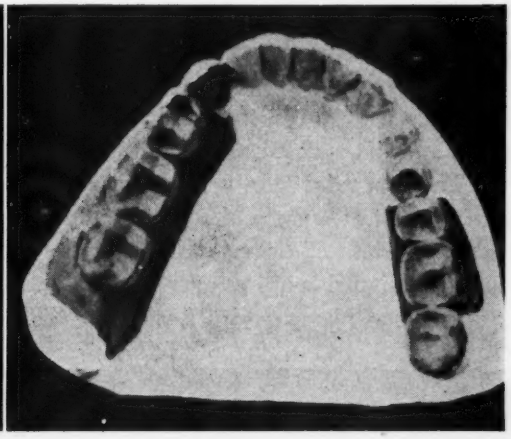

Fig. 19.

Fig. 18.—Cusps and their inclined planes in wax are rearranged to resemble nature for contour, position, and alignment. The flat planes are in harmony with the jaw movements provided by the articulator.

Fig. 19.—Mandibular restorations in wax, showing the left first and second molars formed to imitate nature, and the teeth on the opposite side with abnormal form, but with planes which harmonize with jaw movements.

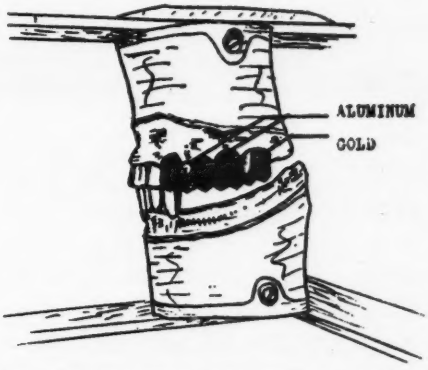

Fig. 20.—The upper cast with the inlays and crowns cast in gold and the teeth in the bridge spaces cast in a low-fusing metal.

To further correlate these cusps with the natural jaw movements, the inlays and bridges are placed in the teeth uncemented. New impressions and casts are made; then the casts and restorations are transferred to the articulator. New checkbites are made, and the jaw movements are again imitated. The teeth are then spot-ground with the aid of chloroform and rouge to a cuspal balance in the finest degree. Owing to the complexities of jaw movements and the technical

procedures, inaccuracies are easily overlooked. For these reasons, the restorations should be transferred to and from the mouth until the opposing planes are further refined to coordinate with the natural jaw movements and to move across each other in the most perfect harmony.

The planes are given shearing ridges by carving supplementary grooves. These ridges are so placed as to create the greatest shearing efficiency with the least amount of strain on the alveolar structure (Figs. 21 and 22).

The occlusal carvings are very easily exaggerated by increasing the depth of the fossae with the thought of aiding nature, but in reality the grinding efficiency is lost and the occlusal balance destroyed to the extent of the malocclusion.

To incorporate the most efficient grinding principles in the occlusal surfaces of artificial teeth, the human tooth presents the best model to be copied. Nature has designed a well-balanced shearing mechanism which cannot be improved. Each cusp is designed with many ridges to cut as multiple shears, and also, designed with inclined planes which harmonize with the slope of the condyle paths when

Fig. 21.

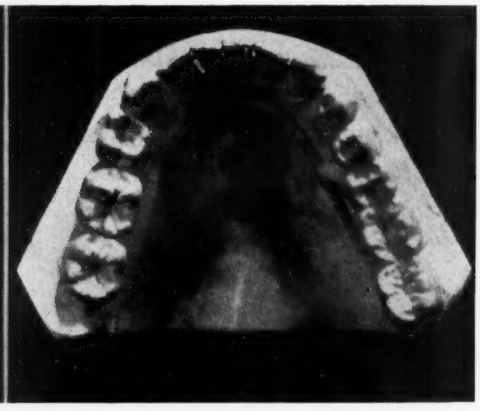

Fig. 22.

Fig. 21.—The maxillary cast of the finished restorations showing the ridges in the teeth which have been placed to imitate nature and create an efficient shearing apparatus.

Fig. 22.—Mandibular cast of the finished restorations.

the mandible moves into the various excursions. This is the most pronounced on the occlusal surface of the maxillary first molar.

I have previously stated that the flat planes of the artificial cusps are correlated with the natural movements of the jaw. This means that each opposing plane is in contact, one flat plane against the other during the various excursions. Now to provide a multiple cutting surface, grooves are sunk throughout these flat planes by carving each cusp individually with small burs, keeping in mind the architectural design of the human tooth.

After the grooves are formed, the restorations have the necessary functional requisites and are seated in the cavities. This procedure requires the utmost care and prudence. A mistake in the seating of an inlay, or one end of a bridge, will unbalance the entire denture, and the supporting tissues will carry the burden of the negligence.

CONCLUSION

It has been my endeavor to suggest a method of restoring an impaired masticating apparatus to a cuspal coordination outside of the mouth on a device capable of imitating the natural movements of the mandible. This is accomplished by: (1) Accurately mounting the casts on the articulator in the proper relation to the hinge-axis. This is done with an adjustable face-bow. (2) Imitating the natural movements of the mandible on the articulator by means of wax checkbites. (3) Shaping and balancing the teeth in wax to provide a pattern of the restorations to be constructed. (4) Correlating the shearing ridges and the mandibular movements so as to create a mechanism that will work smoothly and function with the highest masticating efficiency.

It is true that the ideal is seldom presented. In view of this fact, we must resort to our good judgment and employ the procedure which will come nearest to duplicating the natural masticating mechanism.

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THE CONTROL OF CONDYLE RELATIONS IN THE MANDIBULAR FOSSA

A SYMPOSIUM

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INTRODUCTION

THE SUBJECT of this symposium, "The Control of Condyle Relations in the Mandibular Fossa," has aroused increasing interest in the profession ever since J. B. Costen, M.D., of St. Louis, Mo., published his article "A Syndrome of Ear and Sinus Symptoms Dependent Upon Disturbed Functions of the Temporomandibular Joint" in the *Annals of Otology, Rhinology, and Laryngology,* **43**:1-15, 1934.

Lincoln E. Sanders in The Journal of Prosthetic Dentistry, **2**:589-598, 1952, that the late Bland M. Pippin started treatment of this syndrome at Washington University, St. Louis, in 1936, and kept case histories that unfortunately were lost at the time of his death. Pippin published an article on the subject in the *Illinois Dental Journal* (**12**:429-437, 1943). Rudolph Klicka, of Pittsburgh, advocated the protrusion scheme of occlusion to correct this syndrome in the early 1940's.

R. H. Miller, of St. Louis, in The Journal of Prosthetic Dentistry (**3**:367-373, 1953) quotes Brussell as saying that 57 per cent of all patients over 23 years of age exhibit two or more clinical symptoms of temporomandibular joint disturbances.

Much has been published concerning diagnosis and treatment of temporomandibular joint disturbances, but very little has been said about the technique and the equipment required, and how to go about it. Victor H. Sears (*Journal of the American Dental Association* **45**:179-192, 1952) presented a technique that allows the dentures to come into the anticipated occlusion, but not necessarily associated with opening the vertical dimension.

Originally only one method of treatment was to be discussed on this symposium, but after reflection, the subject was broadened to include other phases of temporomandibular joint difficulties encountered by dentists. With this in mind, several outstanding men, whose work qualifies them as experts, were chosen to discuss the subject in its various aspects.

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LOSS OF POSTERIOR OCCLUSION

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THAT THERE IS a decrease of interarch space following a continued absence of posterior teeth is an accepted clinical fact. That often there also has been a condyle migration, accompanied by alteration in tissue relations of the temporomandibular joint region, seems certain, but these changes are more difficult to demonstrate. When maxillary second molars leave their occlusal imprints on the surface of the mandibular edentulous ridge, as they sometimes do, then the loss of vertical opening is no longer a matter of question. But how much of this change resulted from condyle migration has remained an uncertainty. If there are natural teeth still opposing this area, much of the loss of interarch space may be due to the growth in an occlusal direction of the alveolar bone, as its formative cells are carried along with the periodontium of the extruding teeth. Some more of this space reduction often is due to a hyperplastic increase of the ridge tissue covering. But based on a clinical observation covering many years, it would seem certain that condyle migration, in varying degrees, is responsible for part of this closure.

Certainly it is true that, of the number of patients who lose posterior occlusal support, those who will experience serious retrogressive change of the joint tissues is not a large percentage. But neither is there any question that some of this number will experience more or less discomfort. A few will have excruciating pain at some time after the occlusal contacts of the posterior teeth are lost. Nor is there any question that complete and immediate relief is usually given these patients when a vertical stop is restored at the proper level. If these clinical facts constitute acceptable evidence, then some condyles do migrate to new positional relations following the loss of posterior occlusion and, conversely, their position also may be improved to give relief from joint disturbances.

Whether or not retrogressive changes of the structures which compose this joint are to become uncomfortable seems to be a matter of individual tissue tolerance. In the matter of such tolerance, there is much variation between individuals and, in the same person, from one period of life to another. Sicher has warned that in many patients there will be no marked improvement in such joint disturbances if the treatment is given after mid-life. Particularly may this be true of the disc that has become damaged, it being avascular in structure. These

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facts: (1) that tissue tolerance of the individual cannot be definitely evaluated, (2) that a decline of this tolerance at a later period under different physical conditions cannot be predicted with any certainty at all, and (3) that recovery of a damaged joint tissue is doubtful, all seem to add important emphasis to certain clinical procedures. The first of these clinical procedures is that missing posterior teeth be replaced *as soon as possible,* recalling that joint damage may come early in some patients. A second clinical objective should be to recover as much of the lost vertical opening in the edentulous area as is possible, in this way returning the condyle to more nearly its normal relation to the structures which lie in close proximity.

The accomplishment of balanced occlusion at a *corrected vertical level* now can be done by a method also providing a record of the occlusal path pattern peculiar to that individual. Rather than to accept and to perpetuate the closed vertical relation with which the patient presents, he is given a chance to approach his former and natural jaw position. To attain this result, the patient wears an occlusion rim of special recording wax on a stable partial denture base. This rim must resist all distortion at mouth temperature under heavy-biting forces. To reposition the unused teeth which oppose an edentulous area and to gain all possible improvement in the relationship of the structures of the joint region, the recording rim is left too high. At a first insertion of this path record, the remaining teeth are in a relation that shows a slight opening. But after continuously wearing it (except during mastication) and following vigorous jaw exercises, the remaining teeth are again brought into centric contact.

Achieving an increased posterior vertical opening also causes an occlusal shift in the teeth which remain. As this change occurs, it will center about a line of rotation extending through the most posterior tooth on each side of the arch. Anterior from this fulcrum various occlusal interferences will be developing. Since teeth do not retrude readily, the logical remedy is a process of adjustment by "spot-grinding" as any premature occlusal contacts appear. After occlusal harmony has been re-established, the record-rim is corrected by making the necessary additions to its surface. Again it is left high enough to produce a slight opening of the remaining teeth, and the patient is instructed to wear it continuously (except when eating) and to vigorously grind and champ his teeth at intervals. These exercises should include the wearing of the record during sleep when the eccentric occlusal contacts peculiar to bruxism will be registered. On the patient's return the following day his natural teeth should be in balanced occlusal relationship and his record of the paths of jaw movement complete.

To evaluate this loss of posterior occlusal relations, the following is to be noted: 1. A loss of posterior teeth may result in a decreased interarch opening of the area with an accompanying disarrangement in the occlusion of remaining teeth. 2. This change in jaw relation centers about a line which extends through the posterior tooth of each side of the arch. 3. When there is partial recovery of the vertical opening in the posterior edentulous segment, the jaw relation again is shifted around this fulcrum, with the teeth anterior to this line developing premature occlusal contacts. 4. Since this occlusal imbalance cannot occur until the

increased vertical opening has been established where teeth are missing, it follows that such premature contacts must be adjusted after the occlusion rim has been worn. 5. To prevent imbalance in all of the replaced teeth equivalent to this new interference, the path record must be worn for another period after adequate occlusal balancing has been accomplished (more than one such adjustment may be needed). 6. These clinical observations would indicate that some change in the temporomandibular joint does accompany the decrease and increase of the interarch opening of a posterior area. In no other way can this premature occlusal relation be explained in areas not showing imbalance before the increased opening was made.

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BASIC ANATOMIC FACTORS OF JAW POSITION

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THE CONTROL of the condyle relations in the glenoid fossae is usually dependent upon muscle function moving the jaw to the tooth occlusion, within the limitations of the anatomic structures. If the occlusion is normal, at the proper vertical height, and in the centric position, the jaw position will be normal and the condyle will be in the proper relation to the other anatomic structures of the temporomandibular joint.

However, many occlusions are not normal. Malposition of teeth, loss of teeth, and various other conditions often result in a traumatogenic occlusion. These conditions cause the jaw to be malposed, and the result may be a traumatogenic condition in the temporomandibular joint as well as disharmony with the muscle forces. The malocclusion may vary greatly from a very slight malposition with practically no symptoms, to extreme malposition with severe symptoms.

To diagnose the occlusion and to establish a normal position of the jaw and the condyles, we require a technique to register a jaw position. Many techniques have been devised for this purpose, such as wax checkbites, wax occlusion rims, Gothic arch tracings, hinge axis registrations, and rest position determinations. All of these techniques are apparently dependent upon basic anatomic factors. In all of the methods or techniques used, there are factors of anatomy which either limit or control the centric relation registration. Even the psychology of the patient and the operator are factors in these registrations. However, in this discussion, we will try to limit ourselves to the predominating basic factors of the anatomic structures affecting condyle relations or jaw position.

We could consider a number of the techniques to have a practical approach to the basic factor. In the ordinary wax checkbite with teeth present, the tooth occlusion is recorded. The tooth occlusion is then considered the basic factor of that type of registration because it has positioned the jaw. Sometimes the occlusion itself is used without a wax checkbite. In these techniques, the important consideration is that the tooth occlusion is used as the basic factor for determining the jaw position.

In the Gothic arch tracing technique, the extensions of the movements of the mandible in all directions on a horizontal plane are recorded. From this, a registration of the most retruded position from which lateral movements may be made is secured. This is considered to be the centric relation. The basic factors in this

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type of registration are the muscles as the motivating factor, with the ligaments and the structures of the temporomandibular joint providing the limitation to the movements. This would result in the structures of the temporomandibular joint being the basic or predominating factor in that type of registration.

In the terminal hinge axis technique, apparently the most retruded or most posterior position of the mandible in which a pivotal axis can be developed is recorded. The opening and closing pivotal axis is obtained by moving the jaw open and closed. In this type of registration, the anatomic structures of the temporomandibular joint would also be the predominating factors, and the condyle would be in the most distal position possible at the time of the registration. There seem to be a number of hinge axis movements which may be developed, even in various protruded relations from the most distal position to a fully protruded position, depending upon the training of the individual. In each of these, the position of the condyle would be different, but in the terminal hinge axis, the distal position has been suggested.

Other techniques for locating centric relation use the bone and tissue as the basic factor. Among these are the use of occlusion rims which are placed on tissues, cephalometrics, roentgenograms, and average measurements of anatomic structures. The form and size of bone are primarily dependent upon hereditary factors as affected by acquired conditions. Averages of measurements, such as the length of face, are very interesting and helpful in determining a jaw position. However, because of the variation in individual patients, it does not seem reasonable that the average figures may be applied to one individual to determine jaw position.

The form of bone may be changed by force, that is, by the power of muscles. Wolff's law states that "function determines form." This indicates that muscular forces may affect the bone form. Tissue must be used in registrations, but it is displaceable, so great care must be exercised to determine the position provided by this method.

In the physiologic rest position technique, which requires the jaw to be at the physiologic rest, and the head in a normal upright position, without any effort of function, the jaw position is in the neutral center of muscle forces. Physiologic rest position is a static position. This type of registration has the musculature as the predominating basic factor. Muscles generally maintain their normal length from origin to insertion. However, extreme conditions such as senile atrophy and disease may change their length. Tension and habit patterns apparently affect the muscle length, but they may quite readily be returned to their normal length of function by conditioning.

Briefly, we have considered the following as predominating basic factors in the registration of jaw position: (1) occlusion, (2) the temporomandibular joint, (3) the bone and soft tissue, and (4) the musculature. All of the anatomic structures indicated as basic factors are interrelated in function, but there does appear to be a predominating basic factor depending upon the technique which is used for the registration.

By studying the various registrations in relation to their basic anatomic factors, we might arrive at an opinion as to which factor predominates. A principal factor would be most helpful in the selection or development of a jaw relation registration technique.

OCCLUSION

Tooth occlusion is probably the most commonly used method for jaw relation registration. Tooth replacements are made at the acquired occlusion, and the vertical dimension is opened or closed from that position. We recognize the fact that a very great percentage of occlusions might be considered malocclusions which may cause traumatogenic conditions. This would develop into a traumatogenic condyle position. Because patients have been able to use their teeth at the acquired occlusion, they may continue to use them in that relation. Mouth conditions may be aided and relieved by some corrections from acquired occlusion. However, it is doubtful that a tooth occlusion provides a scientific position of jaw relation from a physiologic standpoint.

BONE AND SOFT TISSUE

Bone and soft tissue may be affected by hereditary and acquired conditions. Bone is helpful in considering the relation of the tooth to the foundation, but there may be a question of a normal relation in the consideration of jaw position because of the fallacy of applying comparative average measurements to an individual. Changes of bone due to traumatic conditions are misleading.

THE TEMPOROMANDIBULAR JOINT

The temporomandibular joint, as used in the hinge axis and Gothic arch tracing techniques, may be affected by a malocclusion. If the malocclusion includes a traumatized temporomandibular joint, it is possible that this traumatic condition would be recorded as the jaw position. In some patients, there is a possibility that the condyles may be forced into a distal position, either unilaterally or bilaterally. The distal or terminal position would be recorded, rather than the normal relation of the anatomic structures in the joint. When the checkbite transfer is recorded at the distal position, the patient may continue to use the occlusion at that distal position, and be somewhat relieved of traumatic conditions by an increased vertical opening and a balanced occlusion. However, the complete treatment of a normal condyle relation may not have been accomplished.

THE MUSCULATURE

The use of the musculature or physiologic rest relations might be complicated by tensions or other conditions. A normal relation is usually possible by conditioning the muscles for a recording of rest position. There may be habit patterns which need to be reduced to permit a normal muscle function. The muscles and their function appear to be the predominating factor over the other anatomic

structures. At the time of the treatment of the patient, the musculature is the predominating factor. Muscles may be returned to a normal function within a reasonable length of time.

By conditioning the patient and recording the unstrained physiologic rest position, there is a good possibility of recording a normal jaw relation. By recognizing and including a consideration of the free-way space, we may diagnose vertical dimension. By closure from rest position, we may record the centric relation, and because the muscles are of equal length, we will have recorded a neutral center without the existence of tipping forces on the mandible.

We may control the position of the condyle and determine the positions of occlusal function by diagnosing the occlusion from the physiologic rest position. The occlusion is placed in harmony with the muscles, and we have established a normal physiologic relation between the occlusion, the muscles, and the temporomandibular joint.

SUMMARY

In normal cases, the occlusion, the temporomandibular joint, the bone and soft tissue, and the musculature all produce the same relations of each to the others, and any one of many registration techniques could be used. In other words, we could employ most techniques and obtain a satisfactory record of jaw relations if normal conditions were present. In addition, there is quite a functional tolerance of all of the factors of jaw relations.

However, to develop a technique which could be applied to all types of patients, normal and those where the factors of jaw relation have been disturbed, we must select a predominating factor which is most nearly normal.

Apparently, the musculature is the predominating basic factor of jaw position. It provides the motivation and the power for the jaw and determines the rest position. The physiologic rest position of the jaw may be used as the diagnostic reference position.

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TENSIONS AND INTERMAXILLARY RELATIONS

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MY FIRST REACTION to Dr. Nelson's invitation to appear on this program was to run and hide. The more I have studied and worked on this subject, the more different angles have presented themselves to contradict and confuse my thinking. Sometimes I long for the confidence and attitudes I had twenty years ago when I was much smarter and knew all the answers. The suggestion that I participate in this discussion with men of great accomplishments and renown gave me the same feelings that A. A. Milne gave one of his characters, Sir Thomas Tom, of whom he says,

"Of all the Knights in Appledore
The wisest was Sir Thomas Tom
He multiplied as far as four
And knew what nine was taken from
To make eleven. He could write
A letter to another Knight
And if he didn't fight too much
It wasn't that he didn't care
For blips and buffetings and such
But felt that it was hardly fair
To risk, by frequent injuries
A brain as delicate as his.

"Or sometimes feeling full of fight
He hurried out to scour the plain
And, seeing some approaching Knight
He either hurried home again
Or hid; and when the foe was past
Blew a triumphant trumpet blast."

It is apparent, from reading the titles to be discussed on this symposium, that all six of us are interested in mandibular function and the temporomandibular joint. It is also apparent that, at this time, our interests are being directed toward treating our patients who have lost (or never had) normal occlusion or intermaxillary relations. There are possibly no points relevant to this discussion which could not be termed controversial. Those of us who have attended dental meetings for many years have heard such points argued, and many of us have joined in the discussion.

I would welcome a physiologist on this platform for, with apologies to all who may be offended, I question how many dentists actually know the physiologic needs

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of the patient or the physiologic limits within which boundaries we must remain to restore and maintain health. I am certain I do not. In my opinion, there can be no set or definite rules in applying a technique unless they can be modified by clinical study and experience. To illustrate: Here is a patient with a painful arthritic temporomandibular joint, with existing inflammatory and degenerative processes, and who cannot demonstrate normal mandibular movement. There are many satisfactory methods of treating this patient, all respecting the *abnormality* and treating that problem first. The one certain technique *not* to be followed would be to attempt to construct dentures, using arrow-point tracings or soft wax checkbites in a conventional manner, without first giving attention to the pathosis. Abnormal muscular tensions resulting from malposition and pain, trismus, cramps, or whatever we choose to call it, make normal mandibular movement and jaw relations practically impossible. Every dentist who treats this type of patient has his pet technique, and I have no quarrels with any, provided the procedure is logical and produces satisfactory results. For years I have treated these arthritic patients and all patients who are included in the group of referred neuralgias resulting from malocclusion with a basic philosophy.

PHILOSOPHY OF TREATMENT

I believe that muscular imbalance may result from any of the following causes (and I have omitted some):

1. Uneven occlusal contacts which force the jaw into an eccentric relationship, sometimes called a "habit bite."

2. Emotional factors which lead to clenching of teeth, and sometimes bruxism, with abnormal, and maybe uneven, wear on occlusal surfaces.

3. Arthritic changes within the joint, either local or coinciding with systemic conditions. This may be characterized by erosion of joint surfaces, by deposits within the joint, or simply by an inflammatory condition within the joint.

4. Traumatic. The case, seen too often for us to overlook, where the mallet and chisel in exodontia have been used with excessive damage to some of the attachments of ligaments.

Regardless of the cause of the pain or tension, I believe our first step must be to relieve this pain. It is only when the patient is pain-free that we can hope to record and restore normal jaw movement. Fortunately, this objective can be reached in a high percentage of patients without too much difficulty. Once this pain is relieved, it will then be relatively easy to locate and register centric relation. The treatment for pain will vary with its severity, but usually relief can be noted within a few days by prescribing:

1. Wet hot packs to the jaws for fifteen minutes three times daily.

2. A soft diet, giving the joints and associated tissue as much rest as possible.

3. Anodynes according to the specific needs of the patient.

4. Sedation to assist in relaxing the patient.

5. In extreme cases, injection of Hydracortone into the glenoid fossa. This is new, but many successful results have been reported. I have used it only twice, but I can report a highly satisfactory reaction in both cases.

At this point in our treatment, we still have a patient with an occlusal disharmony, but one who can be studied, diagnosed, and treated with more accuracy and less discomfort. If the patient is wearing dentures and the errors are not too extreme, new registrations can be made and the dentures transferred to the articulator for study and correction. It may be found that new dentures are advisable, but with a relatively pain-free and relaxed patient, the likelihood of erroneous eccentric registrations is diminished.

For the dentulous patient, this is the time for study casts to be mounted carefully from checkbites and transferred to an articulator with a face-bow. This will serve to demonstrate the points of occlusal interference, and to show premature contacts clearly, as well as the direction and extent to which the mandible is being forced into an eccentric jaw relation by the occlusion.

Temporomandibular joint roentgenograms are usually made at this time, in both the open and closed jaw position. The roentgenograms made with the mouth propped open (usually with three or four 1/8 inch cork discs between the teeth on both sides) give us an opportunity to study the joint surfaces for erosion or calcific deposits. It will also give us an opportunity to consider whether there have been degenerative changes within the joint. If, in the open position, one condyle has advanced far more than the other, we can assume that some changes, either within the joint or in the musculature, have taken place. The views with the teeth closed give us the position the condyles are guided to by a faulty occlusion or uneven muscle tensions. This frequently determines whether corrective treatment will be unilateral or bilateral.

From the study this far, we should be able to locate the cause of the uneven muscular tensions, and by locating the correct centric relation, we should know what must be done to restore the proper vertical dimension and centric occlusion. With restoration of normal occlusal function, in practically every patient, the temporomandibular joint disturbances coming within our field will be satisfactorily relieved. I have not mentioned the term "balanced occlusion" because that may lead me into fields beyond the limits of my assignment here, but I will say that to achieve satisfactory occlusal function, there must be *no interference in any lateral or protrusive movements.*

In routine denture patients, there are two groups where adequate patient preparation is of great importance: First, those patients requiring immediate replacement dentures where the broken-down remaining teeth have forced the mandible to an eccentric position on closing. It is best to grind the interfering points and restore centric relation prior to making the intermaxillary registrations. Second, those patients who have been edentulous, and for whom we are replacing old or ill-fitting dentures. Osseous and soft tissue changes have altered the vertical dimension and the other intermaxillary relations. These changes have taken place slowly and are usually entirely unknown to the patient.

The education of these patients is an important part of the conditioning. A relaxed patient and an educated patient are requisites for success. We do not believe in any arbitrary positioning, but wish to be guided by muscles which are free from tensions. Tensions are abnormal and are beyond the state of tonicity which maintains normal posture.

I have described the procedure of patient education in a recent article in THE JOURNAL OF PROSTHETIC DENTISTRY.[1]

"Patient preparation should actually be under way when the clinical oral examination is being made. There is a great advantage in handing the patient a hand mirror, and asking him or her to follow the dentist during the examination. Good illumination being available, the patient becomes interested and education begins at once. Conditions of the mucosa, hard areas, flabby areas, bearing areas, inflammation, the normal and the abnormal are all pointed out to the patient who, if properly prepared, becomes an associate operator. If the patient has any teeth, either natural or artificial, there is a great advantage in studying the opening and closing movements while the patient is watching in the mirror. It is explained that some of the movement is up and down as on a hinge, and that our problem is to see that the hinge is in the right place. The patient should be told that the mouth must be free of tender areas, the jaws free of pain to pressure or movement, and the muscles of the jaw, the face, and, in fact, the whole body should be relaxed. The patient should understand that some people are more tense than others and that being tense under strenuous conditions is perfectly normal. He should understand that the term "strenuous conditions" can apply to both physical and mental pressures that are present, in varying degrees, most of the time. It can usually be demonstrated, with some guidance of the mandible by the dentist, what is meant by premature occlusal contacts, and how these early contacts cause a shifting of the mandible at the completion of the closing movement. If the patient is uncomfortable or extremely tense, this fact can be brought out, and the need for establishing a more relaxed state is easy to demonstrate."

I have attempted to present my views on patient preparation and conditioning. They represent years of experience and are the results of the thinking of many men. New ideas and approaches are frequently brought into the field, and I am delighted to see so many competent men taking an active interest in the subject. There is plenty of room for all of us.

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ARTICULATOR MECHANISMS FOR INDUCING CONDYLE MIGRATION

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AFTER MANY YEARS of striving to make articulator mechanisms that would reproduce exactly all of the jaw relations found in the patient's head, Sears has shown, by his use of occlusal pivots for the control of condyle relations in the mandibular fossa, that an articulator mechanism should be one that *anticipates* rather than reproduces jaw relations. In fact, the articulator mechanism can be used to induce or permit the desired condyle migrations and state of equilibrium of the mandible.

In bringing about the desired changes, we may use any good dental articulator on which the condyle posts can be lengthened measured distances, and locked at the *new* lengths. The Hanau Model H, the Snow, and the Moyco articulators can be used without modifications except for calibrating the posts.

There is still another method that can be used with the Hanau Model H articulator. That is by the use of wedges of calibrated thicknesses interposed between the ball and its stop in the condyle mechanism of the instrument. All of these techniques have the effect of dropping the mechanical condyles out of their sockets.

It should be clear that merely building up the posterior teeth into supraocclusion as is sometimes done in increasing the vertical dimension or merely raising single molars on right and left sides may, with cuspless teeth, allow the mandible to find its position of equilibrium. But with these methods, the resultant occlusion of the teeth may be unsuitable. The Sears occlusal pivots differ from former methods in that they permit the dentist to work out the occlusions in advance, as they will after the condyle migrations have occurred.

Before an articulator mechanism can be set, and the teeth arranged on the dentures so they will induce condyle migration in the temporomandibular joint, the casts must be mounted on the instrument to be used. The acceptable method involves the use of a face-bow for orientating the upper cast. The average face-bow registration is sufficiently accurate for the purpose. After the upper cast has been orientated and mounted on the articulator, the question arises as to which of three methods should be used to mount the lower cast on the instrument.

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One method is the orientation from rest position advocated by Boos. The second method (the one most frequently used) is by a wax occlusion rim, central bearing point, and a Gothic arch tracing. The third method is the "tap-tap" method. This involves the use of stabilized resinous baseplates simulating the seating surfaces of the finished dentures as nearly as possible, and modeling compound occlusion rims. The patient is instructed to close the jaw with "tap-tap," trip hammer-like strokes until a definite equalized pressure in the molar region is established. Of course, this requires that the occlusion rims be either raised, lowered, or softened as the patient requires during the procedure.

I use the "tap-tap" method in the final try-in because, previously, when I used the wax occlusion rim registrations for patients needing condyle correction, I noticed that after the articulator mechanism was adjusted, and the dentures were finished and delivered to the patient, the patient could close his mouth and have a perfect occlusal contact all around, instead of having an opening between the upper and lower bicuspids when the dentures were inserted. Very shortly the teeth were contacting hard in the anterior portion of the mouth, and there was a space between the posterior teeth where the pivots had been placed. Instead of contacts in the molar region, there were spaces (or at best very light contacts).

It is suggested, therefore, that it is advisable to get as much correction in centric relation as possible before mounting the lower cast on the instrument. The "tap-tap" trip hammer method gets some traction on the ligaments and makes them yield somewhat. The lower cast is then mounted on the instrument.

Boos has found that the Gothic arch tracing is not completely accurate for determining centric relation for these patients. He has found that only in 65 per cent of the patients, centric relation is at the apex of the Gothic arch tracing, and that 35 per cent are not. If you check back on a centric relation record made with a Gothic arch tracing, a choice must be made as to whether you are going to accept the functional working position of the mandible (which will be slightly protrusive of apex of the Gothic arch tracing in function), or whether you are going to accept the apex of the Gothic arch tracing as centric relation. A close study of Boos's articles on this subject is advisable. In this way you can determine which position you are to choose.

The anterior teeth are arranged and tried in the mouth to check the esthetics and returned to instrument. The teeth should be arranged for the pivoting movement only after the try-in. This is done on the instrument, and is not changed thereafter.

In order to provide for the pivoting action as advocated by Sears, it is necessary to simulate, on the instrument, the condition in the temporomandibular joint as it should be when it is corrected—that is, the condyles should be out of contact with the mandibular fossae of the temporal bones. There are many other devices that could be used for raising the condyle mechanisms in the articulator in order to correct the temporomandibular joints of the patients.

As Applegate has intimated, since the condyle *does change* position following the loss of posterior teeth, a large proportion of the patients the prosthodontist sees for the first time fall into this group. After the mandible has come into a

position of equilibrium, and the final occlusal adjustments are made, we find that the pivots continue to function.

Of course, even without articulator post adjustments or calibrated wedges, pivots can be built on the occlusal scheme so that only the pivots make occlusal contact. The disadvantage of this procedure is that at the end of treatment when the mandible has reached a position of equilibrium, the occlusion of the teeth will be defective. If, on the other hand, the teeth are so arranged as to come into the desired occlusion as the pivoting action is completed, the result will be more satisfactory for the tooth occlusion, but not for the condyles.

After the treatment with the Sears occlusal pivots, and when all of the symptoms are eliminated, then, if the operator has his own ideas of the occlusal plane, or type of occlusal anatomy, or the degree of cusp height, he can then make his usual type of dentures.

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METHODS OF MEASURING CONDYLE MIGRATIONS

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ALTHOUGH TREATMENT by means of occlusal pivots can be undertaken without employing recording devices or records of any kind, such devices and records are helpful in checking the results of treatment.

The procedure of recording the positions of the condyles along with a record of the symptoms before placing the occlusal pivots, and then making records of changed positions and changed symptoms as treatment continues, affords an accumulation of data to indicate the general correlation. This general correlation is helpful in planning for the individual case.

Although, as stated, it is possible for the dentist to get results without measuring the extent and directions of condyle movement, he should know something of what these movements may be. He should know what changes to induce and how to bring them about. This knowledge is available.[1]

To measure the drop in the condyles, it is possible to use a vertically adjustable-post articulator. By calibrating these posts, as suggested by Chaignon Brown, the vertical changes can be read on the calibrations. After recording the starting points, it is necessary to make new interocclusal records in the patient's mouth, insert these records between the opposing teeth on the articulator, loosen the posts so they can slide vertically, and read the difference between the starting positions and those produced by the wax records.

This method is fairly accurate for vertical changes, but is not useful in finding the directions and extent of the other changes.

Another method of measuring condyle migrations is by means of roentgenograms of the temporomandibular joint which are taken at intervals. Such roentgenograms indicate the changes in condyle positions, but to date have not proved sufficiently accurate for this purpose. It may also be not advisable to expose the patient to the x-rays.

Another method that can be used satisfactorily to measure the extent of vertical change is by means of casts poured into impressions of the incisors when the teeth are in occlusion in the patient's mouth. These are made at intervals with alginate impression cream. Since the occlusal pivots are usually placed about midway between the condyles and the incisors, the drop of the condyles is approximately equal to the elevation of the lower incisors. Thus, by measuring the elevation of the lower incisors, we have an index of the drop of the condyles. And

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so if we are interested only in the degree of pivoting, it is sufficient to measure the separation of the opposing incisors at the beginning of treatment and, subsequently, as the treatment progresses.

More accurate than any of these methods is the use of mounted casts with correctly related plaster of Paris temporomandibular joints. With such joints it is possible to obtain readings of positional changes of the condyles in all three dimensions of space. This is a method which was used before the making of a special recording device to be described next. It consists in making artificial stone condyles (merely rounded prominences) which are fixed to a lower plaster cast in the same relation as the patient's condyles bear to the lower occlusal surfaces.

With the upper and lower occlusal surfaces occluded by means of a centric relation record in the patient's mouth, the artificial stone condyles (lubricated) are imbedded slightly into the same soft plaster that is used to fix the upper occlusal surfaces in correct relation to the artificial glenoid fossae thus formed. In this way it is possible to establish artificial stone condyles in plaster sockets at centric jaw relation. Subsequent interocclusal records are placed between the mounted occlusal surfaces for comparison. Not only can the drop of the condyles be seen and measured, but so also can any migration in the other directions be observed. Guide marks from which to measure the deviations can be made on the upper and lower mountings in the condyle regions.

All of these methods are less satisfactory than the use of a specially designed condyle migration recorder. This recorder gives, for each patient, quick and easy readings of any positional changes of the condyles.

To use the condyle migration recorder, the upper cast is mounted with a facebow record so that the ends of the condyle shaft are in the same relation to the occlusal surfaces of the upper teeth as the patient's glenoid fossae are to these same teeth in the mouth. In the case of natural teeth, artificial stone reproductions of the teeth are thus mounted; in the case of complete artificial dentures, the dentures themselves can be mounted on their casts.

On the lower member of the condyle migration recorder, each condyle post carries a sagittal transparent plate on which both vertical and horizontal lines 1 mm. apart are ruled. On the upper member, the intercondylar shaft carries pointed ends corresponding to the right and left glenoid fossae. The pointed ends are placed at the centers of the ruled sagittal plates when the centric relation mounting is made. The right and left points thus read zero-zero at the start of the series of recordings. By placing any subsequently made records between the opposing occlusal surfaces, any sagittal, vertical, or horizontal positional changes can be read directly on the sagittal plates.

Then there is the migration of condyles in the lateral direction. This lateral shift can be read on the calibrated horizontal lateral channel of the lower member of the recorder. Thus the changes in all three dimensions can be read directly in millimeters.

The making of interocclusal wax records requires considerable care. The wax should be soft enough to obtain unstrained records, and it should be as thin as consistent with this requirement. It is good practice to make three of

these records for each reading and to check them against one another. If the three are not consistent, other records should be made.

We have here considered only the migrations of condyles in centric relation. While this is perhaps the most important phase, the migrations in the other directions are worthy of study.

Some type of record sheet should be used which will show several successive positions. The one shown in the article[1] referred to has served well, but it is not necessarily the kind best suited to all types of investigation. Whatever record sheets used, they should be of such nature that the operator can record all pertinent data and assemble a fairly large number of them for comparative study. In this way he will better sense the characteristic migrations associated with different conditions and learn what to expect in the matter of positional and symptom changes and more intelligently provide for them.

It is clear that there is a place for the condyle migration recorder, not necessarily in the average practice, but for those investigators who want to study more completely the many implications of the various relations of the condyles to their sockets. These investigators can then relay to the profession the recommendations that grow out of such study.

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THE FUNCTIONALLY GENERATED PATH IN FULL DENTURE CONSTRUCTION

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THE SUBJECT of dentures is one that is near and dear to almost every practicing dentist. Not only does the construction of full dentures make a demand upon every element of scientific training to which the dentist is heir, but it calls for the successful solving of myriads of unexpected developments, each more trying than the last. The final successful set of dentures is man's bravest attempt to imitate nature.

Functional dentures, therefore, are the successful culmination of man's high practice in medical dentistry. They represent the golden goal eagerly essayed by every dental practitioner, and plaintively and confidently expected by every denture patient. The following technique is not original with me, but it is intended as a review of work done by others. It is emphasized that no criticism is intended toward any of the existing accepted techniques, all of which embody great merit in experienced hands.

MOUTH EXAMINATION

A complete examination of the oral cavity and mucosa is of prime importance. Hard areas are noted, such as the existence of tori, whether in the palatal or lingual areas. Undercuts and bony protuberances must be taken into consideration, and surgery employed if their removal is indicated. The tuberosity areas are examined and reduced in size if they are found to be too prominent. The junction of the hard and soft palate is determined by holding the patient's nostrils in approximation and instructing him to attempt to force air through the nose. When the soft palate flexes, a line is drawn with an indelible pencil which delineates the junction. (This indelible line may then be transferred to the impression by repeating the instructions while the impression is in place.) Roentgenographic diagnostic procedure is carried out to eliminate the difficulties arising from impactions, root fragments, etc.

IMPRESSIONS

Preliminary impressions are made in stock trays; from the resultant casts, trays are constructed either of reinforced baseplate material, vulcanite, or one of the rapid and self-activating acrylic materials. It is important that the trays are "reinforced." Both upper and lower trays must be rigid, whatever material is used. The trays are made without handles.

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The upper tray is muscle-trimmed with stick modeling compound. This is done a section at a time by having the patient suck on the operator's finger while he is holding the tray in place. Compound is also applied across the posterior palatal area, but this is not considered a post dam. The post dam is scraped into the final cast. The impression material of choice is one of the impression plasters, rather than one of the zinc exide-eugenol pastes. When using either plaster or one of the impression pastes, it is advisable to drill a hole in the palatal vault with a large vulcanite bur to avoid entrapping air. The hydrocolloid impression materials may be used successfully in perforated shimmed trays without handles. These impressions are removed by pulling on dental floss previously inserted through two anterior perforations in the trays.

Mellott's metal is poured on the lower impression tray on top of the ridge, where normally teeth would be set, confining it in this area by the use of Moldine. The metal should only be about 3/16 of an inch in depth. It acts as a reinforcement and approximates the weight of the finished denture. The tray is tried in the mouth and trimmed for overextension. Overextended flanges are readily discernible to the tactile sense of the operator's fingers when the cheeks are pulled upward. The patient is instructed to elevate the tongue, and to place its tip in each cheek for evidence of lingual muscle impingement. The impression tray is filled with impression material, and a small amount of the material is placed in the mucolabial fold in the mouth. The tray is carried to the mouth and gently teased to place. The hands are removed, and the patient is given no further instruction than to close slightly. The resultant impression will be an approach to a true mucostatic impression. It is to be noted that often there will be little or no retromolar extensions evident. This merely indicates that the muscles will not allow such an extension; to incorporate such extensions would be inadvisable. A sublingual anterior ledge will be present almost invariably, and this definitely should be incorporated into the finished denture.

CENTRIC RELATION AND VERTICAL DIMENSION

The post dam is scraped onto the upper cast prior to the adaptation of the baseplate. A groove 3 mm. wide is scraped into the cast or it is cut with a No. 10 bur. The six upper anterior teeth are selected and arbitrarily secured to the baseplate (Fig. 1). This is tried in the mouth, and the median line, the lip line, individual tooth position for esthetics and cosmetic tooth characterization, as well as the shade to be used, are determined. The lateral incisors may be made to overlap the central incisors, or to protrude slightly, and diastemas may be provided, etc. Compound occlusion rims are made, grooved, lubricated, and seared onto the bicuspid and molar ridge areas. The lower baseplate, with six anterior teeth secured, is then inserted in the mouth. When the patient closes, it is imperative that the lower teeth do not contact the lingual or incisal surfaces of the upper incisors. This might cause a stimulus to guide the jaw which would result in a protrusive record rather than the centric relation record for the vertical opening we are seeking. These lower incisors, therefore, are only of token importance and will be set properly after the occlusion rims are mounted on an articulator.

Softened compound is seared onto the posterior lower ridge areas, and the patient is instructed to close gently without interference until he is told to "hold" at the desired opening. Needless to say, a tutoring session by the dentist is necessary for the patient before any registration is attempted. Many authorities believe in fatiguing the jaw by exercise, and believe that this is a requisite for success. Others place the patient in a horizontal position. One well-known prosthodontist has advocated pulling on the mandible by adhesive strips while the patient naturally resists and closes retrusively. It is my opinion that 98 per cent of all patients give a satisfactory registration after being instructed to place the tip of the tongue posteriorly on the roof of the mouth. The patient may be assisted by placing a pellet of wax at the midline on the posterior border of the upper baseplate with instructions for him to feel for that with the tip of the tongue.

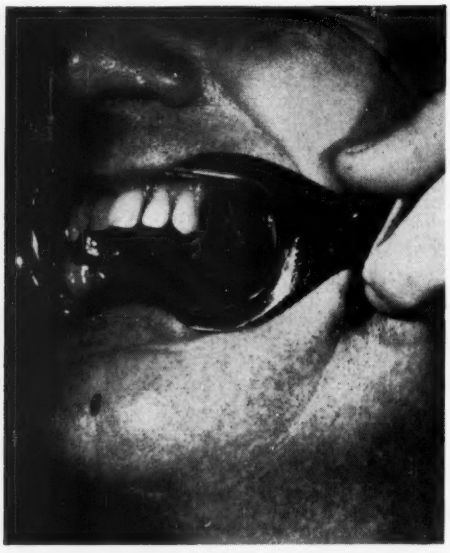

Fig. 1.—Arbitrary placement of upper anterior teeth. Marks on the nose and chin are made for determining the intermaxillary dimension.

The constancy of physiologic rest position and the need for a free-way space have yet to be disproved. Marks or dots are made with an indelible pencil on the tip of the nose and at the cleft of the chin. A caliper reading between these marks is taken after the patient enunciates the sound "Mmmmm." This is the physiologic rest position. The closure into the softened compound is arrested at a point at least 3 mm. less than that caliper reading. When chilled, the occlusion rims are removed. A few minutes later they are replaced and without further instruction the patient is told to close quickly. It can then be observed whether there is any interference, or whether the grooves articulate immediately. A lack of interference indicates that the centric relation registration for that vertical opening is correct.

SETTING THE TEETH

The occlusion rims are mounted on an articulator (Fig. 2). The articulator should be rigid and may or may not be an anatomic instrument. It should, however, be one which *does have* an incisal stop so that, when it is held in the usual manner between the thumb and fingers, no closure of the vertical dimension can occur. The setup is completed with some degree of ease since the six upper anterior teeth are in their desired positions. The occlusal curve is determined with a template for the type of posterior teeth used. The degree of cusp height is reduced in direct proportion to the age of the patient. The lower incisors are placed in their desired relation. The usual attention is to be paid to placing the lower teeth directly over the ridge, etc.

Fig. 2.—Compound occlusion rims mounted in centric relation on articulator.

CONSTRUCTION OF THE LOWER COMPOUND OCCLUDING BLOCK

After trying-in the setup for esthetics and centric relation, the patient is informed that the upper denture is ready to be processed and completed. But (Important Step) *before* curing the upper denture, the lower wax setup is removed and placed in a safe place. A new *well-adapted* lower baseplate is constructed. A compound occluding block with an oversize occluding surface is built on the new baseplate. To assure an accurate fit of the occluding block, it is advisable to tin foil the lower case and readapt the block with one of the zinc oxide-eugenol pastes. The occluding surface should extend at least 3/16 of an inch buccal to and lingual to the posterior teeth, and about ¼ inch lingual to the incisor teeth in the anterior region (Fig. 3). This occluding block is made to the same vertical height as the original tooth setup. It is here that the importance of the incisal stop on the articulator becomes evident.

FINISHING THE UPPER DENTURE

The upper denture is now processed by the injection technique, and finished and polished. At this point, it is imperative to remove the glaze from the biting surfaces of the porcelain teeth by the use of diamond stones. (Etched porcelain surfaces on teeth will obviously masticate better than glazed surfaces.) Tori are relieved with Ash's metal, otherwise no relief is used.

Fig. 3.—Construction of lower compound occluding block.

GENERATION OF THE CUSPAL CLEARANCE PATH

It is at this step in the procedure that true functional balanced occlusion is obtained. The upper denture in the patient's mouth is regarded as though it were his own natural dentition. A stick of the same compound as that used in the occluding block is flamed and peeled with a rotating back-and-forth motion onto the occluding block from first bicuspid through the second molar areas on both sides. It is tempered in water at 140° F. and quickly carried to the mouth. The patient is instructed to tap it closed quickly in various excursive positions. The result eventually will be a composite, generated cuspal clearance path. It is, in reality, a series of Gothic arch tracings, quite arrow-like. The record is correct when there is a minimum of movement evident in the upper denture, regardless of whether the lower jaw chews, slides, or closes anywhere. It is important that no compound has been added in the anterior region. This provides a visible anterior guide so it is possible to be sure that the vertical intermaxillary relationship is not reduced. Finally, compound is peeled onto the anterior region in the same manner as was done in the posterior region. The hardened posterior

area maintains the vertical opening. Then the patient is left alone in the room to work on the hardened generated path for intervals of five minutes of chewing and five minutes of resting over a period of one hour. Examination will then determine the location of the polished facets that indicate interference paths. These are reheated and reinserted, and the chewing is continued.

This step must not be attempted in a hurried fashion as it is the crux of the whole technique. The patients will be able to tell you many things, such as: "It feels as though it belongs, doctor." "I feel a catch right here" (pointing with finger). "It bites too hard in back," or "Something interferes in front." I accept the occluding block as finished when I can detect a minimum of interference, and when the lower occluding block baseplate sucks down into position. This indicates to me that balance is being achieved. A mediocre lower impression will be passable when the superstructure upon it is balanced, and the retention of the finest impressions will be only fair, and will eventually be lost completely with lack of balanced occlusion.

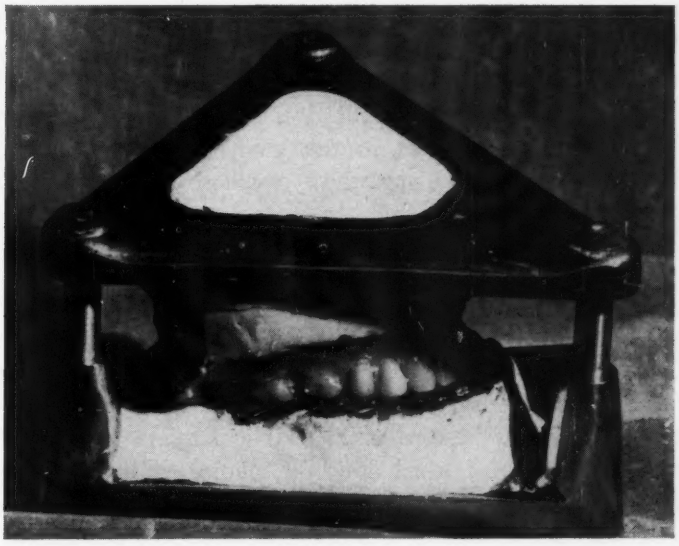

Fig. 4.—Adjustment of the lower waxed setup to the functionally generated path.

If this generated path on the occluding block which sets on the cast could be cured with no distortion, it would be a crude, *but workable* lower appliance adjusted to the existing upper dentition. (To dignify it by calling it a denture would be unfair.) It is a directly chewed-in appliance quite parallel to a directly chewed-in inlay or series of inlays. Any point on the cuspal paths will balance and clear with the existing opposing dentition in any functional position. Our problem, therefore, is simply to apply an indirect technique which will incorporate the wax lower setup that was laid aside while the occluding block was made.

USE OF THE HOOPER DUPLICATOR FOR INDIRECT APPLICATION

The cuspal clearance path that has been generated is carefully painted with a mix of artificial stone, and the lower cast is indexed with grooves or "V" cuts. The lower cast is then mounted with plaster onto the top part of the Hooper duplicator. See Fig. 4. (This is to facilitate movement of the teeth when required.) Wet tissue paper is packed in the tongue space, and the tripod is placed in position over the occluding block. Plaster is built up on the stone negative of the generated path to attach it to the duplicator. The plaster is allowed to harden under the pressure of added weights. The occluding block is removed from the cast and the duplicator, and the lower setup is placed on the cast. The cusps of the teeth are adjusted to touch the stone negative of the generated path in as many points as possible. This does not mean that the cusps should be ground away, but merely that both the buccal and lingual cusps should contact the stone cast of the generated path.

If the path has been carefully developed, very little movement of teeth will be necessary (Fig. 4). Obviously, some will have to be depressed, while others must be elongated. Care is exercised so as not to disturb their buccolingual or mesiodistal relationship, for this would result in improper interdigitation or in an unintentional cross-bite. (Where desired, a cross-bite may be used with no apprehension as to the results.) The dentures are then tried in the mouth again, and observations are made for these errors. If errors are present, they are easily corrected by returned the dentures to the Hooper duplicator and readjusting the teeth. The teeth will balance regardless of where they are placed as long as they are adapted to the generated path.

CURING THE LOWER DENTURE AND REMOUNTING

The more carefully the packing and curing process is carried out the less distortion or change in the vertical dimension will occur. After curing, the cast with the denture still in place on it is remounted in the Hooper duplicator by means of the index grooves in its base. An inevitable increase in the vertical height of the denture will be evident which must be eliminated by the use of diamond stones and an indicator such as a Prussian blue pigment, or a very soft articulating paper. Some critics of this technique have suggested that one of its disadvantages is that the final result is balanced occlusion, but with flat cusps. This is due to a lack of care in the laboratory procedures and is no fault of the theory or practice of the mouth technique. The lower denture is now polished and inserted.

DELIVERY OF THE FINISHED DENTURES

Upon insertion, the dentures will need no correction of the occlusion. Sore spots may develop due to overextension of the borders of either denture, and these are easily corrected by the usual methods. The patient is instructed to wear the dentures without removing them for twenty-four hours, and then return for observation.

CONCLUSION

I feel that this technique is practical, fundamental, and functional. I have used the technique exclusively for over ten years. The same principle, with necessary variations, has been applied in the construction of occlusal correction splints, partial dentures, fixed partial prosthesis, precision partial dentures, full lower dentures made to the patients' natural upper dentitions, and against partial dentures, full upper dentures to patients' own natural or existing partial dentitions, and to immediate single dentures. This technique has produced most gratifying results.

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THE EDENTULOUS MANDIBLE

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THE DESCRIPTION of the edentulous mandible in the standard human anatomy textbooks is woefully lacking in details. As a matter of fact the description of the dentulous mandible leaves much to be desired from the prosthodontist's point of view. It is obvious that from the viewpoint of prosthetic dentistry a detailed consideration of the edentulous mandible is of greater importance than the typical textbook description of the adult mandible with its complement of teeth.

An examination of recent editions of the three most widely used standard textbooks of human anatomy reveals that they dismiss the subject of the edentulous mandible as follows:

"In old age after teeth are lost the walls of the sockets are absorbed; the chin appears therefore more prominent, and the mental foramen is near the upper border. The angle opens out to 140° and the condyloid process is bent back so that the mandibular notch is wider."[1]

"In old age the bone becomes greatly reduced in size, for with the loss of the teeth the alveolar process is absorbed, and, consequently, the chief part of the bone is below the oblique line. The mandibular canal, with the mental foramen opening from it, is close to the alveolar border. The ramus is oblique in direction, the angle measures about 140°, and the neck of the condyle is more or less bent backward."[2]

"In old age, after the fall of the teeth, the alveolar margin is absorbed, the angle formed by the ramus and body is again increased, and the mental foramen lies nearer the upper margin . . . in old age it becomes exceedingly porous, often so soft that it may easily be broken."[3]

Inasmuch as it may logically be assumed that the readers of this JOURNAL are more or less familiar with the typical textbook description of the adult dentulous mandible, such a description here is superfluous. Rather the objective aimed at in this article is to describe the edentulous mandible in greater detail than is usually done in the standard textbooks of human anatomy, and to correlate the anatomic features of the edentulous mandible with the soft parts related to it.

It is obvious that the most characteristic feature of the edentulous mandible is the absence of an alveolar process, due to resorption following the loss of

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the teeth, as a result of which the height of the body of the mandible appears to be greatly reduced. Moreover, it is well known that the amount of resorption of the alveolar process is quite variable depending, among other factors, upon the period of time elapsing since the complete loss of the normal dentition. For example, Fig. 1 illustrates a number of edentulous mandibles showing considerable variation in the amount of resorption of the alveolar process that has occurred. Because of this variable factor, upon which the structural features of the edentulous mandible per se for the most part depends, any gross description of the edentulous mandible is likely to be true only for a particular one, or for all those exhibiting

Fig. 1.—Some examples of edentulous mandibles illustrating variations in morphology.

the same degree of resorption—a situation unlike that of the normal adult mandible, which, though exhibiting minor variations, is more or less uniform.

The edentulous mandible selected for description in this article is illustrated in Figs. 2 and 3. It may be argued that it is not typical but represents an extreme case. Nevertheless, it is representative of the edentulous mandible of the aged individual, deprived of his normal dentition over a long period of time, and illustrates the degree of resorption to which the mandible is liable.

TERMINOLOGY

In describing an edentulous mandible, for example, such as the one illustrated in Figs. 2 and 3, several questions arise concerning terminology. Inasmuch as the alveolar process is usually defined as that portion of the mandible which contains and supports the teeth, and since it is known to be more or less resorbed following the loss of the teeth, the question arises as to the correct term that should be applied to the remaining ridge after the alveolar process undergoes resorption.

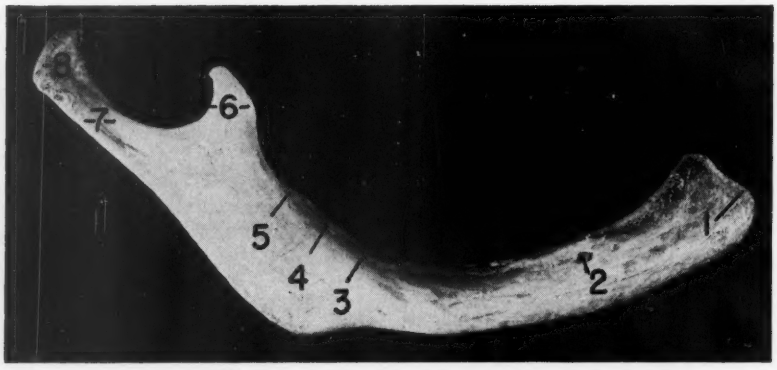

Fig. 2.—Lateral view of an edentulous mandible. *1*, Mental protuberance. *2*, Mental foramen. *3*, External oblique line. *4*, Buccal shelf. *5*, Retromolar fossa. *6*, Coronoid process. *7*, Condylar neck. *8*, Condylar head.

Fig. 3.—Medial view of an edentulous mandible. *1*, Genial tubercles. *2*, Mylohyoid line. *3*, Lingual tuberosity. *4*, Retromylohyoid area. *5*, Internal oblique line (temporal crest). *6*, Groove of mandibular neck. *7*, Crest of mandibular neck. *8*, Coronoid process. *9*, Condylar neck. *10*, Condylar head.

As a matter of fact, even in the normal adult mandible with all of the teeth present, no definite boundary line between the alveolar process and the body of the mandible can be demonstrated grossly. Since the roots of the mandibular teeth extend to various depths in the bone, those of the third molar occasionally extending beyond the level of the mandibular canal which is described as being located within the body of the mandible, the question arises as to whether the alveolar process is ever completely resorbed or disappears in the edentulous mandible.

Various terms have been applied to the existing ridge which remains after the loss of the permanent teeth and the resultant resorption of the alveolar process. In the absence of an alveolar process as it is generally conceived, it does not seem logical to refer to the existing ridge as "alveolar ridge" and a like reason holds true for the term "dental ridge." Attention is called to the illogical use of the term "gingival ridge." The gingiva is generally defined as the mucoperiosteum which surrounds the teeth; it differs in position and microscopic structure from the alveolar mucosa, which is the term applied to the mucous membrane covering the buccolabial and lingual surfaces of the alveolar process.[4] In short, following the loss of the permanent teeth, the gingiva, according to definition, ceases to exist as such. In the light of these considerations it is recommended, therefore, that the most logical term to apply to the remaining ridge is "residual ridge," since it is in reality a residue of the former or original ridge.

Attention is also called to the use of the term "alveolar bone" (lamina dura), which is generally defined as that layer of bone which lines the alveoli and immediately surrounds the roots of the teeth. It is not to be confused with the bony or alveolar plates of the alveolar process; these plates, indicated as labial, buccal, and lingual, are composed of compact or cortical bone continuous with that of the body of the mandible and are separated from the alveolar bone proper by cancellous or spongy bone.[5] Histologic studies of the repair of tooth sockets following extractions prove that the alveolar bone proper (lamina dura) resorbs, and the socket fills in with cancellous bone and is covered by cortical bone on the crest of the ridge.[6] As a result of what is commonly called "disuse atrophy," the cortical and cancellous constituents of the alveolar process then gradually undergo resorption to some extent.

GROSS ANATOMIC DESCRIPTION

The edentulous mandible illustrated in Figs. 2 and 3 presents several striking features in comparison with the normal adult mandible with all of the teeth present. The mental foramen, although subject to a slight variation in position, is usually found midway between the inferior border of the body of a dentulous mandible and its alveolar crest, about 13 mm. inferior to the apex of the second bicuspid. As shown in Fig. 2, this foramen is located almost on the crest of the residual ridge. Likewise, it can be seen that the mylohyoid line is situated along the entire length of the lingual border of the residual ridge and terminates distally in a prominence, called the lingual tuberosity, which lies lingual to, and flush with, the distal end of the ridge. Since the mylohoid muscle takes origin from the mylohoid line, it is obvious that during the life of this individual, this muscle was attached to the lingual margin of the ridge. Proof that this is probable is furnished in Figs. 4 and 5 which illustrate attachments of muscles to edentulous mandibles that somewhat resemble the one under consideration.

The mylohyoid line divides the lingual aspect of the body of a dentulous mandible into two areas, an oral area superiorly and a cervical area inferiorly, each marked by a fossa which is produced in the living state by the presence of

a salivary gland, the sublingual superiorly and the submaxillary inferiorly. On edentulous mandibles, such as are shown in Figs. 2 through 5, the oral area has disappeared. The absence of this area accounts for the fact that in place of an alveololingual sulcus between the alveolar process and the tongue in mouths with this type of mandible, there is instead a more or less marked elevation (sublingual crescent), produced by the presence of the sublingual gland in the floor of the mouth.

Situated on the oral area just superior to the mesial extremity of the mylohyoid line in the incisive region are the genial tubercles or mental spines, which on this mandible lie almost upon the crest of the ridge. Since these spines serve for the attachment of the genioglossal and geniohyoid muscles (Fig. 4), it is evident that in the living state these muscles would require relief on an artificial denture base.

The chin appears quite pronounced, as is typical with edentulous mandibles on which the alveolar process has undergone considerable resorption in the incisive region. The presence of a chin on the mandible occurs only in the human species and is explained on the basis that the lower dental arch and its supporting alveolar process fail to grow as far forward as does the body of the mandible. The resorption of the incisive alveolar process undoubtedly creates an illusion of the chin being more prominent. The chin is normally marked by a triangular elevation, the mental protuberance, the lower angles of which produce the mental tubercles, and the upper angle continues along the line of the symphysis producing a faint vertical ridge. However, on this edentulous mandible, the mental protuberance and the ridge overlying the symphysis, rather than assuming a vertical position, are flattened somewhat. On either side of the symphysis of a mandible on which the alveolar process is present, there is a depression, the incisive fossa, which gives origin to the mentalis muscle and the quadratus labii inferioris (depressor labii inferioris). On an edentulous mandible lacking an alveolar process, this fossa is greatly reduced in size and flattened so that it faces upward rather than forward; the muscles which arise from it are attached almost on the crest of the residual ridge (Fig. 4).

In view of the location of the mental foramen, mylohyoid line, genial tubercles, and incisive fossa in relation to the crest of the residual ridge on this edentulous mandible, in view of the greatly diminished vertical height of the body, of the fact that it is almost oval in outline from its lateral to its lingual surfaces with its inferior border more rounded and thicker, and because of the fact that the mental protuberance faces almost superiorly rather than anteriorly, it may be assumed that practically all that remains of this edentulous mandible in the region of the body of the mandible itself, is a portion of the body. In short, it would appear that even the body of this mandible shared somewhat in the resorptive process.

The coronoid process of the normal adult dentulous mandible is usually longer than the condyloid process and points almost directly superiorly in line with the anterior border of the ramus. However, on this edentulous mandible, and on several others which were examined, the coronoid process is markedly shorter than the condyloid process and curves sharply posteriorly giving it a

hooklike appearance. As is typical, the sharp anterior border of the coronoid process is continuous with that of the ramus, which in turn continues diagonally anteroinferiorly along the lateral aspect of the body as the external oblique line, which on this mandible is only faintly distinct beyond the molar region. In the latter region it is particularly well marked; it is grooved anteriorly, evidently by the external maxillary artery; posteriorly it is very likely grooved by the anterior border of the masseter muscle (Fig. 2).

The buccal shelf is described as the flat, sometimes grooved, area located between the external oblique line and the crest of the alveolar ridge in the molar region. There can be no question about the presence of a buccal shelf when the molar teeth are present, since it is readily recognizable. However, when the crest of the alveolar ridge resorbs following the loss of the molar teeth, it may be questioned as to whether a buccal shelf any longer exists as such since, as on this edentulous mandible, it seems to become incorporated with the residual ridge, which actually is not ridgelike in this region but wide and flat, extending from the external oblique line to the lingual tuberosity (Fig. 3). As a result of the flattening of the residual ridge on this mandible, the lingual tuberosity appears sharply outlined in comparison with its counterpart on normal adult dentulous mandibles.

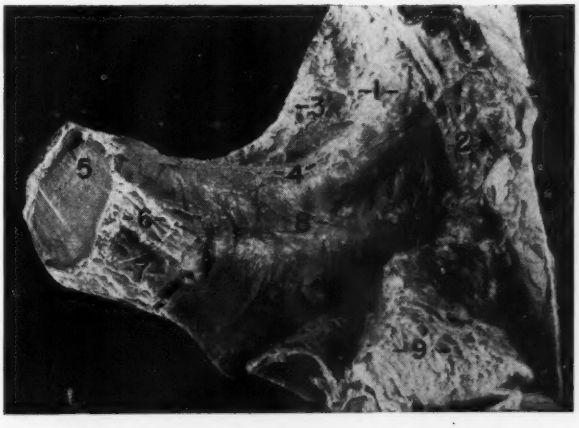

Fig. 4.—Lingual aspect of dissected edentulous mouth. *1*, Retromolar pad. *2*, Retromylohyoid curtain. *3*, Buccinator muscle. *4*, Residual ridge. *5*, Mentalis muscle. *6*, Genioglossus muscle. *7*, Geniohyoid muscle. *8*, Mylohyoid muscle. *9*, Tongue (root).

In addition to the alveolar process of the maxilla in the molar region, the buccinator muscle takes origin from the pterygomandibular raphe, the buccal shelf, and so-called buccinator crest (retromolar triangle) of the mandible. The latter is a small, rough, triangular area just distal to the third molar on the crest of the alveolar ridge of a dentulous mandible. To it are attached, in addition to fibers of the buccinator muscle, the pterygomandibular raphe and some fibers of the superior pharyngeal constrictor muscle. On an edentulous mandible the fibers of the buccinator muscle, which usually arise from the buccal shelf, take

origin from the flattened residual ridge (Fig. 5). No evidence of a buccinator crest was found on this edentulous mandible or any that were examined; it is evidently resorbed following the loss of the molar teeth. The three structures normally attached to it must of necessity re-establish a new attachment to the disal end of the residual ridge following resorption of the alveolar ridge, and, since it is not recognizable as such, the reattachment evidently fails to stimulate enough new bone formation to maintain it or to produce a substitute.

Situated on the anteromedial border of the ramus is the internal oblique line (temporal crest), which is somewhat rounded on the typical dentulous mandible and serves for the insertion of the deep tendon of the temporalis muscle. It forms the medial boundary of a triangular depression called the retromolar fossa, which in the living state is occupied by a soft pad of tissue, known as the retromolar pad. On this edentulous mandible, the internal oblique line is quite sharp, as a result of which the retromolar fossa appears deep (Fig. 3).

Fig. 5.—Coronal section through level of oral cavity. *1*, Buccinator muscle (note attachment to residual ridge). *2*, Buccal shelf (note flatness). *3*, Mylohyoid muscle (note attachment to residual ridge). *4*, Sublingual crescent. *5*, Tongue.

THE CONDYLOID PROCESS

The condyloid process on this edentulous mandible is longer than the coronoid process and like the latter is bent backward slightly (Fig. 2). Moreover, several other features are to be noted; a pterygoid fovea normally present on the anterior

aspect of the neck of the condyle for the insertion of the inferior head of the external pterygoid muscle is scarcely distinguishable; the anteroposterior diameter of the head of the condyloid process is quite small; the articular surface of the head is confined almost entirely to the superior aspect rather than being located more on the posterior than on the anterior surface, which is typical on dentulous mandibles; and the tubercle on the lateral extremity of the head for the attachment of the temporomandibular ligament is very pronounced. Most of these features were observed on several edentulous mandibles that were examined. Especially characteristic of these mandibles are the backward angulation of the condylar neck, the narrow anteroposterior diameter of the condylar head, and the diminished articular surface. In view of the fact that edentulous individuals without benefit of artificial dentures protrude the mandible during mastication in order for the upper and lower ridges to contact, and thus pressures are exerted between the condyle and the articular eminence, the suggestion is offered here that this practice over a long period of time with the resultant pressure atrophy on the condyloid process produces these characteristic features.

Sicher[7] describes what he calls the "crest of the mandibular neck," which is a bony ridge extending anteroinferiorly from the medial extremity of the condylar head to the anterosuperior margin of the mandibular foramen, and serves as a buttress of the ramus to transmit the forces of mastication to the condylar head from which they are transmitted to the base of the skull. This ridge is evident on the edentulous mandible, although it is not prominent. Sicher also describes what he terms the "groove of the mandibular neck" which runs parallel with and posteroinferior to the crest terminating at the mandibular foramen. On this edentulous mandible, the groove as well as the mandibular foramen are especially well marked (Fig. 3), although it is to be noted that a lingula is not recognizable.

The retromylohyoid area of the mandible is a smooth surface on the medial aspect of the ramus between the mylohyoid groove and the lingual tuberosity, and in the living state forms the lateral boundary of the retromylohyoid fossa, which is a pocket-like depression at the distal end of the alveololingual sulcus.[8] This area on the edentulous mandible under consideration is very narrow (Fig. 3) and suggests that even the ramus of this mandible has undergone some resorption. In fact, the anterior border of the ramus gives the appearance of having shared in resorption with the other parts of the bone.

Naturally there is no way of knowing what the maximum width of the ramus of this mandible or any dried edentulous mandible was prior to the loss of the permanent teeth. However, in an effort to arrive at the conclusion that in its present morphologic state, the width of the ramus of this mandible has been reduced by resorption, the following test was applied: the mean average width of the ramus of forty dentulous mandibles selected at random was obtained and compared with that of the same number of edentulous ones. The mean average width of the rami of the dentulous mandibles measured was 3.3 cm., with a minimum of 2.45 cm. and a maximum of 3.89 cm.; the average for the edentulous ones measured was 2.9 cm., with a minimum of 2.15 cm., and a maximum of 3.70 cm.

I am well aware of the fact that the validity of this test is subject to question, particularly in the light of modern statistical and cephalometric roentgenographic methods. However, the results seem to indicate that the rami of edentulous mandibles tend to narrow and therefore must share in the resorptive process with the other parts of the bone. It seems reasonable to expect that with the loss of the permanent teeth, regardless of whether or not artificial ones are substituted,[9] the muscles of mastication cease to exert as much force on the mandible as formerly, with the result that their bone-stimulating function is reduced, and hence all parts of the bone tend to undergo disuse atrophy.

No figures were obtained in this study on the degree of angulation between the rami and body of edentulous mandibles as such data did not seem pertinent.

It is concluded from this study that the edentulous mandible differs from the typical adult dentulous one described in standard anatomy textbooks in several respects, differences that are particularly significant to the prosthodontist, and attributable for the most part to disuse atrophy resulting from the loss of the permanent dentition. Most of the anatomic features characteristic of an edentulous mandible, such as described in this article, are either those that are absent, or those that assume a different location because of the disappearance of parts due to resorption; on the other hand, some parts are characterized by a change in their morphologic shape and appearance. These characteristics, it would seem, are of sufficient importance to the practitioner of modern dentistry, especially prosthetics, that a more detailed description of the edentulous mandible in standard textbooks of human anatomy is warranted.

SUMMARY

1. The objectives of this article are to describe the edentulous mandible in greater detail than is usually done in standard textbooks of human anatomy and to correlate the anatomic features of the edentulous mandible with the soft parts related to it.

2. Questions are raised concerning the usage of certain anatomic terms in the light of existing structural conditions.

3. The most characteristic and well-known feature of the edentulous mandible, from which the permanent teeth have been missing for a period of time, is the absence of a well-defined alveolar process resulting from resorption due to disuse atrophy.

4. As a result of the resorption of the alveolar process, the vertical height of the bone in the region of the body is greatly diminished; the mylohyoid line, genial tubercles, and incisive fossae with their attached muscles lie near or upon the crest of the residual ridge, as do the mental foramen and its contained vessels and nerve; some structures, such as the buccal shelf and buccinator crest, lose their identity; while others, such as the chin and lingual tuberosity, seem to be exaggerated.

5. The coronoid and condyloid processes exhibit certain characteristic features: the former being shorter than the latter and both bent backward; the anteroposterior diameter of the condylar head is diminished; its articular surface is confined to its superior aspect and the lateral tubercle is quite pronounced.

6. Evidence is presented to indicate that the rami and body of the edentulous mandible may share with the alveolar process in resorption.

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A CRITICAL ANALYSIS OF THE MUCOSTATIC PRINCIPLE*

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FOR SOME, the investigation of the mucostatic principle has probably done more toward imparting a better understanding of the theories of denture prosthesis than any other single phase of study. Whether the principles involved are completely sound or utterly absurd is, in reality, of little importance. The fact remains that there are some good thoughts behind all theories and a thorough examination of these thoughts leads to a better understanding of those with which we are already familiar.

Moreover, the perfecting of the alginates as impression materials, to the point of ever-increasing popularity, has made many men inadvertently practitioners of mucostatics. These reasons coupled with the age-old desire to find a method by which tissue preservation can be accomplished, thus eliminating the necessity for relines, make a re-examination and a re-evaluation of the mucostatic theory important at this time.

HISTORY

The discovery of the mucostatic principle as we know it today is generally credited to Mr. Harry L. Page, an engineer, about 1938. The word itself was coined by Dr. Carrol W. Jones,[1] of Englewood, Calif., to indicate a principle of impression making and denture base construction in which the oral tissues are not distorted nor under stresses of any type, but are maintained in an undisplaced or normal relationship. The retention of the bases constructed in this manner is credited to "interfacial surface tension."[2]

With these as its major concepts, a supposedly new principle of denture construction was set forth. However, it soon came to light from an examination of dental literature that these same concepts had been presented as early as 1886, and doubt arose as to whether Page had discovered anything new at all. Richardson's[3] text of 1886 had mentioned the necessity of taking impressions of tissues at rest, as well as stating that "adhesion by contact" was one of the most important factors in retention. Wilson,[4] in 1920, also referred to adhesion; and Cox,[5-13] a Melbourne practitioner, in 1927, called the same phenomenon surface tension.

Pryor[6] reported that Drs. Montgomery and Burgess, of Los Angeles, presented a paper at the American Dental Association meeting in Houston, Texas, in 1941,

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which evidently contained much of the same material that Page later presented. Pryor further intimated that they had originally engaged Page to promote the sale of their trays, but that he had made some slight changes, and in alliance with the manufacturer of a chromium alloy, had presented and sold the material as his own. Pryor[7] also stated that they brought suit against Page and a financial settlement was made out of court.

In spite of this controversy, let us credit Page not with the discovery nor even the rediscovery of a principle, but rather with the explanation of the physical laws of the hydrostatics pertinent to the denture problem. Regardless of the past history, Page and his associates have done more toward stimulating increased study and re-examination of old theories than anyone else had done before.

PRINCIPLE

Basically, mucostatics was presented as a principle not a technique. It includes the physical laws (most of which are based on hydrostatics) applicable to the impression problem and the relationships of these laws to the retention and stability of full dentures. Disregarding all other retention factors, the mucostatic principle credits interfacial surface tension as being the only retentive means of importance. Essentially the technique consists of the procurement of an impression, which is an absolute negative of the ridges in their normal passive state. From this impression is produced a cast and finally a denture base which will have a perfect contact relationship with the underlying tissues. So exact is this duplication that at no time during the procedure is a separating medium used for fear that its presence will affect the fit of the denture base.

Since acrylic resins possess inherent qualities making them incapable of absolute reproduction, the use of metal baseplates is highly recommended. After the construction of the metal bases the mucostatic denture is carried through much the same as any other, with the exception of greatly shortened flanges in the finished denture.

The acrylics, that have come to replace vulcanite and have been so universally acceptable because of their greater hygienic and esthetic qualities and ease of manipulation, have been responsible for a great number of ill-fitting dentures. It has been shown[8] that following processing, and before an acrylic resin denture is ever removed from the cast, a space exists in the vault and tuberosity regions as well as in the labial flange area of the upper. Comparable spaces also exist in the lower denture. These spaces were not present to as great an extent with vulcanite nor are they as common if metal bases are utilized. These spaces certainly have a very important effect on retention, be it a product of adhesion or interfacial surface tension. Thus, the use of properly fitted metal bases is a step forward in denture construction. There are several metals from which well-fitted baseplates can be made, and the successes from these various metals certainly refute the theory that there is only one suitable alloy. The advantages gained in original fit and its maintenance, thermal conductivity, increased tissue tolerance, and the reduction of bulk and weight are not to be surpassed.

INDICATIONS

Mucostatics was originally introduced to the dental profession, not as a universal cure-all for difficult denture patients, but as a different approach to the age-old problem of prosthesis. According to the advocates of mucostatics most of the profession's difficulty in all fields has stemmed from an incorrect approach to its problems. The search has constantly been for an infallible technique with no inquiry into the principles involved. Page[2] has stated that we have always had technique versus principle and how versus why. Technique itself is merely the practical application of principles, and if the principles are unsound, the most elaborate and painstaking technique certainly is doomed to failure. In any field of prosthesis where the condition to be treated is never the same, and where the method used is as variable as the number of men using it, there can never be an exact and infallible technique. Mucostatics does not claim to be the answer to our prayers for such a technique, nor does it even claim to be indicated in all instances, but it does, by explaining the principles involved, offer some greater understanding of our problems.

Much has been written to establish definite indications for mucostatics; varying opinions come from those who use it exclusively and those who use it only in the presence of loose, flabby tissue in the lower arch. It is natural, since most of our troubles arise from lower denture construction, that any new principle will first be applied there. Pryor[6] summed up the plight of the dentist very aptly when he said, "Many of them wend their weary way with troubled conscience eternally seeking that denture heaven where lower dentures, especially, are trouble free."

RETENTION AND STABILITY

Retention and stability are factors of paramount importance in the success of any denture and a complete understanding of the methods for obtaining both of these, as well as the theories behind them, is a necessity. Stability refers to the ability of the denture to remain steady in function and is in no way related to retention, although generally speaking, a stable denture is a retentive one.

The factors given as important in denture retention have included everything that could be mentioned as having a remote connection. Richardson[3] gave the two forces that he regarded important: adhesion by contact, and atmospheric pressure. These are the oldest and most quoted factors of a long list to which many others have been added. Those retention factors regarded as most important will be considered throughout this paper, and an attempt made to evaluate them in relation to the mucostatic principles and laws of hydrostatics.

Almost all authorities are in agreement that adhesion by contact or interfacial surface tension is the outstanding retention factor; they differ only in the term applied. Leverages, the correct relationship of the teeth to the ridges, as well as to the teeth of the opposing arch, and balanced occlusion are also recognized as important. Atmospheric pressure and gravitation, although long considered, are now relegated to minor roles. Peripheral seal, a controversial factor, is

given a great deal of credit by some and little by others. Last, muscular coordination, a seldom mentioned although extremely important factor, is completely ignored by the mucostatic advocates while others place this in a class with adhesion.

In principle, the greatest departures of mucostatics from the other accepted theories of denture retention include: complete disregard of atmospheric pressure and peripheral seal in retention; the thought that muscle trimming is not only of no use but is detrimental; the theory that tissues cannot be compressed, and the belief that no distinction can be drawn between hard and soft tissue.[9] These departures, as well as the previously mentioned complete disregard for muscular retentiveness on properly contoured and polished surfaces, show the change in thought concerning denture retention.

IMPRESSION TYPES

There are, in general, two main types of impression techniques employed in denture construction. One is the so-called stress or pressure type which displaces tissue and which is criticized by the mucostatic advocates as being responsible for the tissue changes beneath the dentures constructed from it. The other, the nonpressure or rest impression, is the basis of mucostatics.

It seems that the question for consideration lies in what is the purpose of an impression. Few will challenge the answer that the most accurate reproduction of the ridges and bearing area is the aim, regardless of the impression technique. Certainly no one then will criticize any method giving such a reproduction. In theory the mucostatic impression does just that, and with the possible exception of the treatment of the post dam area, which, according to some, needs functional placement, this impression theory certainly has something to offer.

Since the goal of the impression procedure is to fit the denture to the patient, not to fit the patient to the denture,[10] the devotees of mucostatics use an impression material softer than the softest denture-bearing tissue, placed in a tailor-made tray which does not impinge on tissue at any area and seated without pressure. The tray then settles while the patient's mouth is completely relaxed, giving a most accurate reproduction of the bearing area at rest.

Many materials have been presented for the various impression methods. From plaster in the 1880's, the profession has run the gamut of modeling compounds, waxes, impression pastes, and hydrocolloids up to the present time when alginates are in favor. However, it seems that the emphasis should be placed not on the type of material, but within limits, on its manipulation. A consideration of the varying ridge types in relation to impression materials will bear this out.

The bearing areas are of varying types in each patient. Let us consider tissue that is hard and dense with no flabby attachments. It is reasonable to believe that regardless of the type of impression material or impression technique, the results will appear identical. After all, as Page[2] pointed out, it would matter little in making an impression of a steel bar whether the method used was one in which water was allowed to freeze about it or one in which lead was pounded around it, the results would be the same. Let us consider again the oral cavity which may have a large amount of easily displaced tissue on the ridges. A non-

pressure impression of such a condition does not displace any of the tissue and remains stable when released. Tissue displaced during an impression procedure will often "float" the impression out of place when the pressure causing the displacement is released. This is a common cause of a lack of stability in the denture base. Thus, the type of material used and its manipulation certainly plays an important role in the result obtained. As shown above, the problem here is not in the prevention of settling of denture bases under functional stresses but the prevention of the lifting of the denture when pressure is released.

ELASTICITY

A consideration of tissue elasticity will, in part, show the importance of this problem. If tissues are originally moved by the impression they will continue to be moved by the finished denture. This displacement is held responsible for the ultimately harmful resorption of underlying bone accompanied by discomfort and loss of retention, and resulting in the necessity for rebases. Since the only position at which tissue is content is that of is normal rest position, the theory is easily understood as to why the base should be constructed to maintain that position.

COMPRESSION

Compression of tissues is a much used phrase which has been criticized highly in mucostatics. Many dentures are said to be constructed by a compression technique in which the tissue is compressed in order to obtain peripheral seal and better adaptation of the bases and in an effort to force the tissues to some functional position. That there is actual compression of tissues has been doubted for quite some time,[3-6] but it remained for Page to give the first truly scientific explanation of this phenomenon.

According to Pascal's law, pressure on a confined liquid will be transmitted equally throughout the liquid in all directions. Page,[2] in claiming that compression of tissues does not occur, bases his theory on this law, maintaining that the oral tissues closely approximate the condition of a confined liquid. If this premise be accepted, the reasoning, as was set forth by Page, is rational and sound.

The law applied to the tissue condition, makes it evident that under pressure everything moves or nothing moves, that tissues, like any fluid, will not move in part. Further, it has been established that tissues are composed of solids and liquids in the ratio of one to four. Soft tissue is predominantly water, and by checking the bulk modulus of compression of each of its components it is seen that all of these are even less compressible than water. Water, the major and most compressible component of soft tissue, has a bulk modulus of 4.7×10^6, which means that under an impressional force of thirty pounds the tissues would be compressed to .000094 of their volume.[2] Because of this, let the word "compressed" be used advisedly; better still, let it be replaced by "distorted" or "displaced." It is exceedingly doubtful that all of those using the expression in the past meant that the tissue was actually compressed. Rather it may be considered an expression which, like so many others of common usage, came to mean a variety of conditions.

ATMOSPHERIC PRESSURE AND PERIPHERAL SEAL

In some denture patients where it is readily seen that displaceable tissue is present, stress type bases exhibit quite sufficient retention and do not float upward when pressure is released. There is obviously some force strong enough to overcome the natural tendency of the tissues to return to normal with their consequent unseating action on the denture. Many retentive points have been considered, among which atmospheric pressure and peripheral seal received most credit. According to hydrostatics neither of these phenomena exists as a retentive factor. Many men have doubted their role from Wilson,[4] in 1916, to the present.

To say that atmospheric pressure and peripheral seal never exist as factors in dental retention is pure folly. Both do exist and can be proved to do so. However, by the same token it is not claimed that either is everlastingly present, though peripheral seal may last indefinitely.

Since these go hand in hand, one experiment may be used to show their function. A stock tray is selected and trimmed short of any contact with tissue; to the periphery a pencil thickness of beeswax is adapted and luted; the tray is then warmed and muscle trimmed so that only the periphery of wax is in contact, yet positive retention is exhibited. If a section of this wax then be removed no retention is present.[14]

The old vacuum chamber serves as another example. It is merely a slight space created on the tissue side of the denture base approximately at the center of stress. Following swallowing which theoretically reduces pressure beneath the denture base, a positive retentive force is observed. Subsequently, the tissue hypertrophies, filling in the chamber; thus putting an end to its function. Obviously then, the vacuum produced by a space could not be maintained over a long period. Atmospheric pressure can be utilized when the denture base is partially unseated without breaking the seal. This is seen in some functional movements of the denture when the base is tilted, forming a space between it and the bearing area. This, in effect, forms a vacuum which tends to reseat the denture.[5-8]

As a criticism of peripheral seal the question is asked why two dentures for the same patient with varying extension of the lingual flange may be equally retentive? Also, if peripheral seal were accomplished, how could it be maintained following numerous adjustments trimming away the flange areas? Beading the periphery or extending it into the mucobuccal fold is an easy procedure with a wide range of tolerance.[11] Thus, an overextended denture, which may cause no discomfort to the patient, may have quite a bit trimmed away, yet the seal may be maintained for some time. A lasting, hermetically sealed denture is doubtful since too much pressure is required. However, an attempt to extend the denture and thus prevent the entrance of air beneath the base will continue to aid in retention after the seal per se has long since vanished.[13]

FUNCTIONAL DISPLACEMENT

How many loose-fitting dentures are seen to tighten immeasurably by the mere addition of a post dam? Here, according to many, is the only area where tissue can be moved successfully. A slight placement of the soft palate insures seal as well as forming a nonskid device[11] to combat the natural component of force of the hingelike movement of the mandible.

Since tissue can be moved to advantage in the post dam area, some advocates of the stress type denture claim that this procedure should be carried a step further. They maintain that in function the denture is forced to a functional position, and thus the entire denture base should be made at this position. The fallacy of this idea, though, lies in the fact that there is no method by which two impressions can be made with exactly the same amount of pressure forcing the tissue into the same functional position time and again. Neither are the forces in the mouth the same from time to time, nor are they exactly equal to the impressional pressure. It has long been realized that denture retention and stability are more a problem when the dentures are at rest than when they are in function with forces tending to seat the appliances. Hence, since the problem occurs at rest, let the denture base be constructed at rest.

INTERFACIAL SURFACE TENSION

The argument that mucostatics simply coined a new term and substituted it for "adhesion by contact" has been presented many times before. Actually, the term seems a matter of individual preference, since they have come to be practically synonymous.

Surface tension is inversely proportional to the thickness of the moisture layer between the two surfaces. This indicates that the better the complementary fit, the more attraction the surfaces will have for each other. Also, the old surface tension experiment with two glass slabs and a film of moisture shows that its greatest power is exhibited against forces perpendicular to the surfaces. The power diminishes as the force used to separate the contacting surfaces approaches parallelism with the long axis of the liquid film. Thus, two moistened glass slabs cannot be pulled apart but may slide readily on each other.

The film layer forms a meniscus at the edges of the approximating surfaces which any outside liquid tends to wash away. The technique of flooding the edges of a tightly adherent impression destroys this meniscus, increasing the depth of the fluid layer, causing loss of surface tension. This same condition occurs in the presence of excess saliva.

The application of this principle can also be used to explain, in part, why a denture, originally tight, becomes a floater. Stress impressions often reduce the fluid layer over the tissues either by forcibly squeezing out the film or by their setting actions. A thin and consequently very powerful film remains. As the tissues resorb, the space between the denture base and oral tissues increases causing the liquid film to increase in depth, thus losing surface tension and affording a better opportunity for the oral fluids to destroy the meniscus.

FLANGE CONSIDERATION

One of the most unique, and consequently most criticized aspects of the mucostatic principle is the consideration, or lack of it for the flanges. Since surface tension is the only retentive force considered, radical design of the flanges results. It was shown that the power of surface tension is effective, only against perpendicular forces. Thus, it is concluded that only those ridge surfaces that are horizontal have any retentive value. The flange areas, being parallel to the force of dislodgement, are thought to have no bearing on retention, except for a slight mechanical value in preventing lateral displacement.

Dykins[12] compared the lingual flange with the wheel of a railroad car, which does not grip the rail, but extends downward on the inside, as a mechanical lock. He considers a lingual flange carried 1 or 2 mm. over the crest of the ridge quite sufficient to effect a mechanical aid in the prevention of lateral displacement.

It seems that here the mucostatic people have become overly enthusiastic, in disregarding all possibility that there might be other retentive factors, in addition to the one which they describe as all powerful. They completely overlook two of the most important principles of prosthesis, that of muscular retentiveness and the possibility of increased trauma in a confined area.[13]

Wilson's rule of denture coverage[4-6] remains as valid today as when first presented in 1920. He said that all foundation area possible should be covered so long as the base does not interfere with normal muscle function. Extending the denture base to, but not encroaching upon, functional muscle attachments gives greater distribution of masticatory stresses. It gives a greater area for surface tension as well as enabling us to contour properly the surfaces for added muscular retention. By this extension, peripheral seal is attempted, facial contour rebuilt, food lodging prevented, and tactile discomfort to the tongue eliminated.

Fish[5] considers a denture to be composed of three surfaces: the impression, the occlusal, and the polished surface, of which he believes that the latter is the most important because of muscular retentiveness. Since this factor is disregarded in mucostatics, a different explanation is offered as to why patients are able to maintain obviously ill-fitting dentures satisfactorily.

Generally, this phenomenon is explained by the fact that there are sufficient areas of dense tissue that were undistorted by the original impression to maintain retention against attempted recovery by such tissues as were distorted. They also credit the use of full, soft plaster impressions from which a great number of dentures were made, as in reality, being a mucostatic impression.

RELINES

Mucostatics claims that the atrophy and resorption that is the rule under stress type impressions need not occur universally. It is said that, since under a mucostatic impression, the tissues are recorded in a contented position, they will comply with, rather than fight, the denture base. While little evidence has been shown to prove that tissues do not resorb under mucostatic dentures, some claims point to that fact. Addison[15] made casts at regular intervals for three and one-half years following the insertion of mucostatic dentures and all are said to be identical.

It is doubtful that the necessity for relining will ever be completely overcome. All tissues change, edentulous mouths with no appliances show resorption—a product of age if nothing else. However, more research at holding relines to a bare minimum is indicated, and it hoped that something will come to light in the near future.

ARTICULATION

In any denture case there are three goals to attain: esthetics, function, and comfort. The first, esthetics, is a matter of art and can be achieved, to a greater or lesser degree, depending upon the skill of the individual operator and the desires of the patient. Function is extremely important, because no matter how the denture looks or feels to the patient, if it cannot be used, it is a failure. However, the dentist can do only so much in the pursuit of function, the patient must train himself to use the denture. Comfort, though, must be supplied by the dentist and nothing should be overlooked in the attempt to obtain it.

The search for comfort has brought about the extended use of the roentgenogram in edentulous patients, and this alone has been responsible for immeasurable gains in this field. In addition to this, mouth preparation and careful surgical procedures have gone far in eliminating adverse conditions which would doom any denture to failure. Yet, the most overlooked and perhaps the most important feature is to be found in the denture itself, that of faulty articulation.

Generally, the first step in the elimination of sore spots is the relieving of the denture base even though the articulation is suspected of being at fault. This attempt at conserving time and a giving the patient quick relief accomplishes nothing more than chasing the sore spot around the mouth and results in the eventual ruin of the denture base. Regardless of the impression technique from which the base is constructed, it alone is seldom the cause of soreness. Invariably it can be traced to some tooth or cusp malalignment, which may or may not be in the same arch or on the same side of the mouth, yet destroys balance and upsets stability. These causes generally can be found quickly by the use of a full wax checkbite, in which the high spots cut through. They can then be eliminated by a spot grind and over-all balance can be restored by milling the denture, either on an articulator or in the mouth. This procedure alone, during the adjustment period of the dentures, will reduce the number of adjustments and will result in a base which has not been destroyed by indiscriminate grinding.

Disregarding the impression technique and articulation method followed, if the patient is left with a painful denture, the denture is most assuredly unsuccessful. If the dentist will take more time with the finished denture on insertion, and perfect balance and working bite, with the elimination of cuspal interference, the results will speak for themselves. It should be remembered that during the processing of acrylic, there are dimensional changes which may result in some malalignment, regardless of the perfection observed at the try-in.

CONCLUSION

Probably the greatest single reason for the unpopularity of the mucostatic principle was its method of presentation. It came, not from a member of the profession, but from a lay person claiming to have found something new. Practically all the material on the subject was published in an advertising medium of a private company. Special type trays, impression and baseplate materials were also advocated and the technique was presented for monetary return. Its devotees became so enthusiastic that many old concepts were completely disregarded or unceremoniously exploded. It caused much ill feeling from remarks hastily and, at times, inadvisedly made. Yet, the fact remains, that there is much good thought behind the principles involved, and it has added much in the way of understanding the problems pertaining to denture construction, as well as introducing a new mode of thought.

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FULL-MOUTH EXTRACTION AND IMMEDIATE DENTURE INSERTION IN ONE OPERATION USING GENERAL ANESTHESIA

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IN THIS operation the patient is hospitalized, the teeth are all removed under general anesthesia, and the dentures are inserted before the patient regains consciousness.

The cardinal objectives of this operation are to rehabilitate the patient as rapidly as possible, to provide the patient with a denture of high functional and esthetic quality, and to keep discomfort, both physically and psychologically, at a minimum.

When first embarking upon this method of treatment three years ago, a multitude of questions arose: Would this be safe for the patient? Would the "shock" of removing all of the teeth be too great? Would the postoperative discomfort be too great to tolerate the denture in place in the mouth? Would the dentures become dislodged during the postoperative period? Would it be possible to retain the initial denture during the postoperative healing period and still maintain that denture as the final denture? Is a denture which has been relined to keep pace with alveolar healing just as good as a denture placed in an edentulous mouth after six months? To each question experience has given us an affirmative answer.

The techniques contemplated were all accepted, well-known procedures; the final plan of operation was a combination of several methods modified to meet the exigencies of the case. The unusual aspects of the operation are found in integration of abilities and skills of the physician, dentist, and anesthesiologist, working with hospital facilities to meet the modern need for an improved and simplified immediate denture service.

The purpose of this article is to summarize the general plan of operation followed in this case and in forty-one others that have been completed during the past three years.

PREOPERATIVE CONSIDERATIONS

When careful examination of the mouth and teeth reveals the need for the extraction of many teeth and replacement by a complete denture, the patient is advised of the several techniques by which the operation may be performed.

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If the patient has elected a full-mouth extraction under general anesthesia and immediate denture insertion, a consultation is requested with his physician. The operative procedures are explained carefully to the physician and he is requested, specifically, to determine the physical fitness of the patient for this operation.

Fig. 1.—Patient's natural dentition before the initial impressions are made.

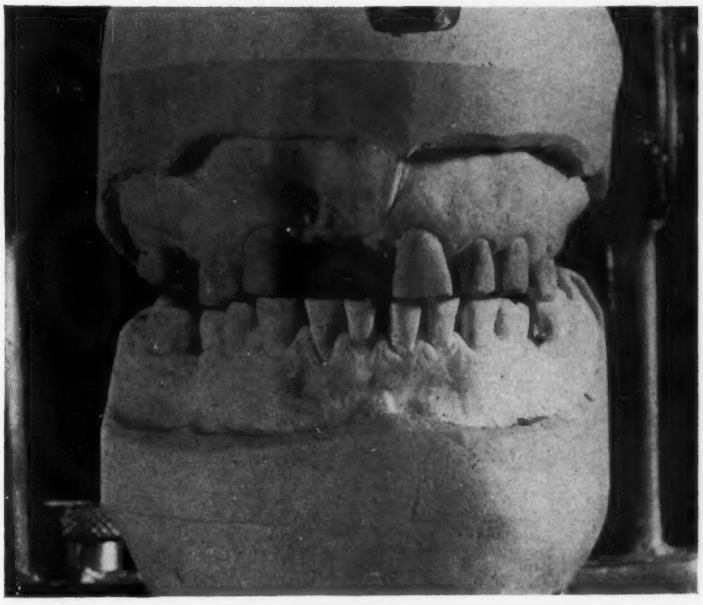

Fig. 2.—Final working casts mounted on the articulator.

Should physician and patient consider the operation desirable, an appointment is made for the presurgical preparation of the mouth. At this time, the teeth are scaled and cleaned and instructions for maintaining a hygienic condition in the mouth preceding surgery are given. Following this, initial impressions are made (Fig. 1).

IMPRESSIONS

Accurate detail in teeth, gingiva, and other tissue areas is desired in the initial impressions. Hydrocolloid is used as the impression material. Accuracy in peripheral extension and muscle trim is desirable; however, minor inaccuracies will soon be corrected as the denture is to be relined within a few weeks following insertion. Conventional techniques can be employed after healing is partly or wholly complete. The impressions are filled with stone and the casts are mounted in occlusion on an articulator (Fig. 2).

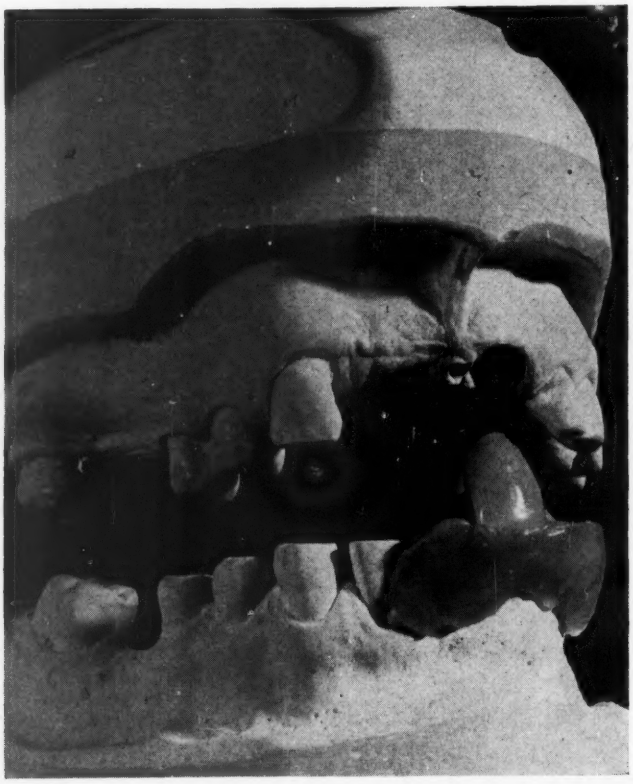

Fig. 3.—A pseudosocket has been carved, and an artificial tooth is contoured.

ARTICULATION

As an esthetic reproduction of the natural dentition is desired by most patients, each anterior tooth is cut from the cast, and an area about 2 mm. deep, a pseudosocket, is dug in the alveolar ridge (Fig. 3). The denture tooth is shaped and placed in this area (Fig. 4). One by one the anterior teeth are thus replaced (Fig. 5). The posterior teeth may be replaced by this method or by any technique the dentist desires. In either case, the teeth must be cut from the casts and the artificial teeth recessed 2 mm. into the ridge.

WAXING

After the teeth have been set, one thickness of baseplate wax is used to form the flanges of the lower denture. Tin foil is burnished onto the palate of the upper cast, gently removed and trimmed to the impressions of the necks of the teeth. One thickness of baseplate wax is then adapted to the palate, and the tin foil is carefully replaced upon the wax. This gives an accurate reproduction of the contours of the palate for its phonetic and masticatory functions. This method is described by Pound.[1]

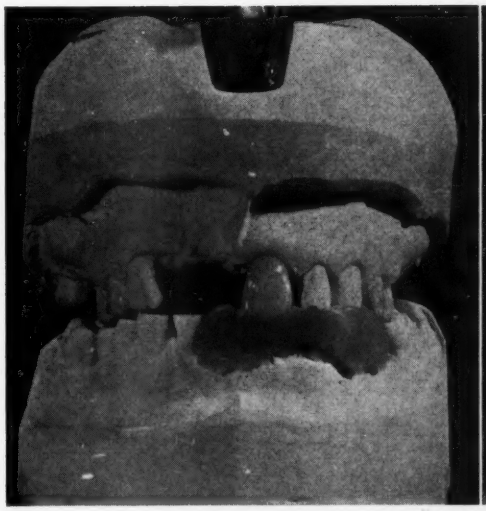

Fig. 4.

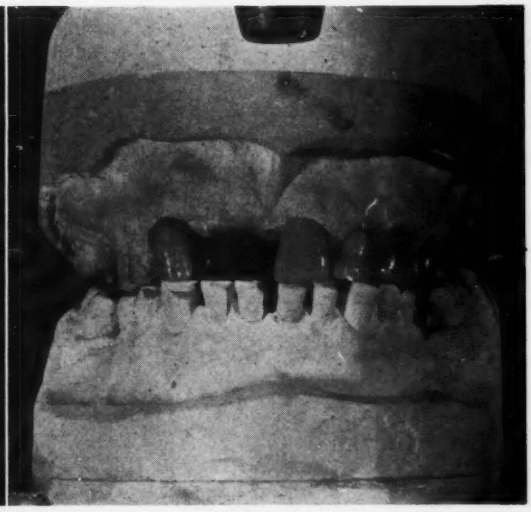

Fig. 5.

Fig. 4.—The central incisor is in position.

Fig. 5.—The artificial anterior teeth have been contoured and are in position in their pseudosockets.

REPRODUCTION OF GINGIVAL DETAIL

The gingival portion of the anterior area of the maxillary stone cast is not disturbed in order that it may be reproduced exactly in the finished denture (Fig. 6). The cast is waxed from the reflections to a line about ½ cm. above the gingival crest in the anterior region. One thickness of baseplate wax is used over the buccal surfaces of the upper cast. It is carved around the necks of the teeth. A thin coating of mineral oil is applied to the stone cast in the anterior gingival area.

FLASKING AND BOIL OUT

The denture is flasked with a mixture of one-half stone and one-half plaster as the investing medium. After boiling out and cleaning, a liquid type of separating medium is applied. The casts are seen for the first time without teeth in Fig. 7.

CONTOURING TO SIMULATE PLANNED ALVEOLECTOMY

The sockets cut into the ridges remain as reference points. The casts are contoured in keeping with a minimal removal of alveolar bone (Fig. 8). Care must be taken not to disturb the cast beyond the line halfway from the crest of the ridge to the intended denture periphery, as no bone is removed from this area during the operation. The gingival area in the anterior portion of the upper cast is cut away to equal the anticipated alveolar bone removal. An adequate thickness of acrylic is to replace this amount of stone. At this point, hydrocolloid impressions are made of the denture casts for the construction of surgical templates in clear acrylic to be used as guides during the actual alveolectomy.

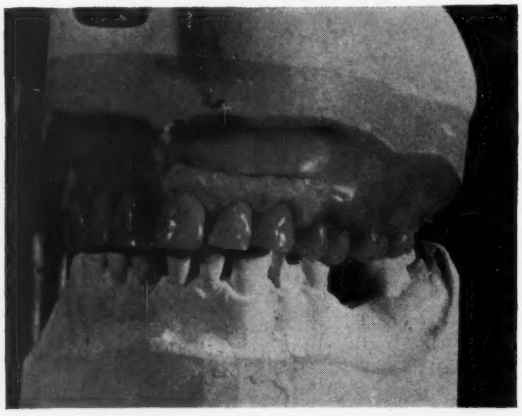

Fig. 6.—The denture is waxed and ready for flasking. The anterior gingival area is not covered with wax.

HOSPITALIZATION

The patient is usually hospitalized the evening before surgery is scheduled. Most patients now carry some form of hospitalization insurance which partially or completely covers hospital expenses, except the actual dental fee. A few hospital plans now include the dental surgical fee. A complete blood count, urinalysis, serology, and bleeding and clotting time are recorded. Antibiotics, in accord with the patient's past history, are used as a preventive measure to ward off infection. The patient is then seen by the anesthesiologist.

GENERAL ANESTHESIA

The prime requirements regarding the safe conduct of anesthesia for this operation are preoperative examination by the anesthesiologist, proper premedication and selection of anesthetic agent for each individual patient, safeguards against explosions, absolute control of the airway at all times, and careful observation of blood loss. The operation should be performed only in a hospital where all possible safeguards are available to the patient.

The procedure of full-mouth extraction is inherently one in which there is considerable blood loss. Hemostasis cannot be obtained by conventional surgical technique. Normal clotting mechanisms must be relied upon, although a continuous locking suture approximating the gum margins helps reduce the blood loss. This situation necessitates use of tracheal intubation, as it is the only method that provides absolute control over the airway in the presence of bleeding in the oral cavity. In order to meet these requirements, detailed planning, thoughtful preparation, and actual practice by the surgical team of dentist, anesthesiologist, and hospital personnel is necessary.

Fig. 7.

Fig. 8.

Fig. 7.—The working cast in the lower half of the flask. Pencil lines mark proposed alveolectomy to be performed upon the cast.

Fig. 8.—The working cast with the area of proposed alveolectomy trimmed and shaped.

TECHNIQUE OF ADMINISTRATION

Following induction, the patient is rapidly anesthetized to second plane, surgical stage anesthesia, at which time intubation of the trachea is performed either by the nasal or oral route. The nasotracheal technique was used on the first few patients in order to provide more freedom for manipulation in the mouth. The nasal route

is sometimes traumatic to the nasal mucosa with consequent possibility of secondarily involving the paranasal sinuses of the ipsilateral side. Therefore a change to the oral route was made. This change has not interfered with the procedure in any way. With the oral route, a larger endotracheal tube can be used than by the nasal route, thereby reducing the resistance to breathing.[2] The nasotracheal technique can be used equally as well if the mechanics of the procedure require maximum freedom in the mouth.

Intubation is facilitated, in some instances, with various muscle relaxant drugs in conjunction with cyclopropane, cyclopropane-ethyl ether, thiopental sodium oxide-oxygen, nitrous oxide-ethyl ether-oxygen. D-tubocurarine HCl, Flaxedil, and succinylcholine chloride have been the muscle relaxant drugs used. The selection and dosage of these drugs is based on the anesthetic agent used and the physical status of the individual patient. There is no "routine anesthetic procedure."

Following intubation of the trachea, the patient is reconnected to the anesthetic machine. The anesthesia is conducted in the usual manner using circle or to-and-fro carbon dioxide absorption technique. Blood pressure, pulse, respiration, use of indicated fluids, careful scrutiny over tidal exchange using assisted respiration in order to assure maximum oxygenation and prevention of carbon dioxide accumulation,[3] all must be carefully observed. None of these points can be minimized.

Cuffed endotracheal tubes are not used as there is no particular indication for them. To facilitate maintenance of pharyngeal toilet, a small "vaginal pack" is placed in the pharynx just before the surgical procedure is begun. Its presence easily traps small bits of bone from the alveolectomy. The conventional suction apparatus is used also.

ANESTHETIC AGENTS

The choice of anesthetic agents revolves around the physical status of the patient and presence of explosion hazards. Electric motors used by the surgeon are not explosion proof. The belt driven dental engine and hand piece constitute a definite static spark hazard. When this type of equipment is to be used, the operation is performed under thiopental sodium "curare agent" -nitrous oxide-oxygen. If it becomes necessary to use hazardous equipment after the surgery has started under an explosive technique, the patient can be changed to the nonexplosive anesthetic agent with ease and safety.

Cyclopropane, cyclopropane-ethyl ether, nitrous oxide-oxygen ethyl ether, ehyl ether-oxygen, thiopental sodium-nitrous oxide-"curare agent"-oxygen have been used for this operation. For the most part, a modified "balanced"[4] anesthesia is preferred to the use of only one agent. This modification excludes the injection of any "local anesthesia." Topical anesthesia may be used in an ointment applied to the endotracheal tube if desired. Also, topical anesthesia as a spray, or by nebulization, may be applied to the pharynx and larynx prior to intubation. The use of topical anesthesia particularly reduces bucking on the tube and spasm of the intercostal muscles sometimes seen under thiopental sodium anesthesia.

The choice of agents is made when the anesthesiologist examines and talks to the patient. The preanesthetic evaluation takes into account the patient's cardiovascular-renal status, metabolic activities, respiratory state, fluid and electrolyte balance, and mental attitude. It cannot be overemphasized that a routine anesthetic procedure is undesirable. Each operation must be planned for the individual. This same thought holds for the preanesthetic medication.

Fig. 9.—The "vaginal" pack and endotracheal tube are in place. The patient is prepared for surgery.

COMPLICATIONS

The possible anesthetic complications hinge around peculiarities of the agents used, complications of the endotracheal technique, and complications resulting from continued bleeding into the mouth with collection of blood in the pharynx. The discussion of each of these sets of possible complications is beyond the scope of this article but are recognized by well-trained anesthesiologists.

SURGICAL PROCEDURE

Since extracting all of the teeth is little different from removing a few teeth at a time, it is best that each surgeon carry out the procedure according to his own preferences (Fig. 9). A "vaginal pack," moistened in a saline solution, is placed in the pharynx. There is no fear of blood or osseous fragments entering the trachea. The maxillary arch is usually operated first. After the teeth are removed, the

alveolectomy is performed referring constantly to the surgical template. The running, noninterrupted suture is very effective and a great time saver (Fig 10). The maxillary denture is tried in and then removed while the mandibular arch is operated. The dentures are inserted before the vaginal pack and endotracheal tube are removed (Fig. 11).

Fig. 10.—The alveolectomy has been completed prior to the insertion of the denture.

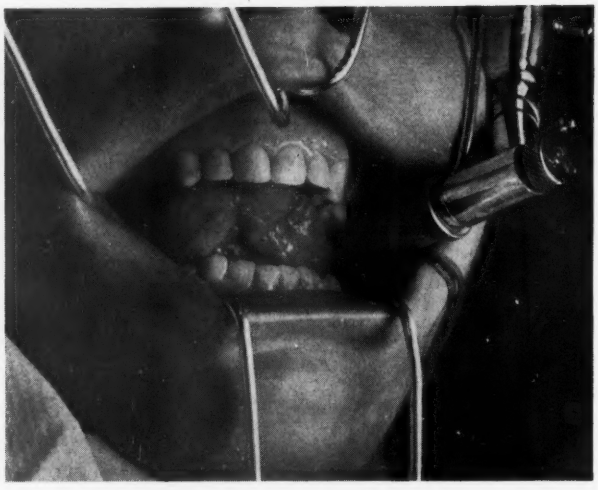

Fig. 11.—The denture is inserted. The endotracheal tube and throat pack are still in place.

After the anesthesiologist has removed the pack, an airway is placed in the patient's mouth (Fig 12). The endotracheal tube is removed and as patients begin to regain consciousness, they bite on the airway, and later they keep their denture teeth clenched until they are completely conscious. Dentures do not dislodge during the postanesthesia period.

POSTOPERATIVE

Immediate postoperative orders are generally: (1) No mouth washes, (2) antibiotics as history and examination indicate, (3) suitable analgesics for postoperative pain, and (4) diet as tolerated.

After a twenty-four hour period patients are ambulatory and many are ready to leave the hospital. The dentures are still not removed. Warm saline mouth washes are used at frequent intervals. Medication for postoperative pain is ordered if needed. Several patients experienced no postoperative pain and refused medication. Three patients had considerable edema in the buccal areas and one patient had swelling under the eyes, but recovery was uneventful. All were discharged after two or three days of hospitalization.

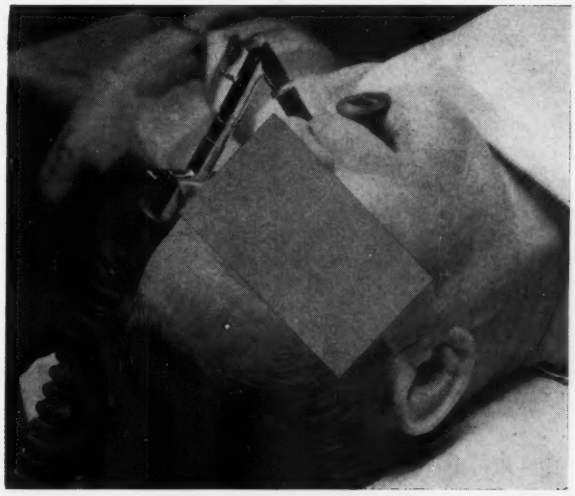

Fig. 12.—The dentures have been inserted. The pack has been removed, but the endotracheal tube is still in place. An airway has been inserted.

POSTHOSPITAL PROCEDURE

Patients are instructed to report to the dental office immediately after leaving the hospital. The dentures are not removed for forty-eight hours. Some have been left undisturbed for seventy-two hours. They are first removed in the dental office. The patient rinses the mouth gently with a warm saline solution containing 1 per cent hydrogen peroxide. The mouth is examined for pressure points. These areas are relieved by a minimum of adjustment. The patient is then instructed how to remove the dentures, how to keep them clean, and advised as to diet and various methods of mastication. The sutures are removed after five to seven days, and the patient is seen at subsequent intervals.

RELINING

Relining is most important. The denture as it is placed in the patient's mouth on the operating table is complete in its external aspects, but its impression surfaces, especially those in the alveolar ridge areas, are only temporarily accurate. Resorption takes place noticeably only in the alveolar area (Fig. 13). Only a

A.

B.

C.

Fig. 13.—*A*, Cross section of a denture being relined showing alveolar resorption in the anterior area. *B*, Cross section of a denture showing resorption in the posterior alveolar region. *C*, Cross section of a denture showing the palate as the reference area.

Fig. 14.

Fig. 15.

Fig. 16.

Fig. 14.—A reline impression in an upper denture. Note that the impression material does not cover the palate.

Fig. 15.—After the cast is poured and separated from the denture, the impression material is cut away from the border.

Fig. 16.—The denture being relined is sealed to the cast with wax which is covered with tin foil in the lower half of the flask.

technique for relining the denture in the area of resorption was necessary. Healing is usually rapid and uniform. The lower denture is usually relined first.

The buccal shelf,[5] the retromolar pad, and the occlusion against the opposing denture are the reference areas. A free-flowing material is used to make the impression in the denture. The completed impression should contain virtually no impression material, if any, on the buccal shelf areas of the mandibular denture or the palatal area of the maxillary denture (Fig. 14). This helps guard against changing the vertical dimension and centric relation. Denture bases are pierced with a No. 4 round bur in the bicuspid areas on either side in some cases to permit excess impression material to escape.

A cast is poured into the impression in the denture. After the stone is set hard, the denture and the impression material are carefully removed from the cast. Broken fragments of impression material are removed from the cast and the denture. The impression material is cut back about 5 mm. from the border of the denture (Fig. 15), and the denture is replaced on the cast. It is sealed to the cast with wax, and invested in the lower half of the flask. The denture is tin-foiled to a line about 3 mm. below the teeth (Fig. 16). This assures an invisible junction between the reline acrylic and original denture base material. Then the flasking is completed.

An alternative technique can be employed at this point to avoid separating the denture with its reline impression from the cast. After the cast is poured into the reline impression, the denture can be flasked in the lower half of the flask, tin-foiled, and the remainder of the flask filled with investment. The denture is then completed as before. We have used both methods and find both equally accurate. The periphery is very difficult to clean at the time of the boil out, but with the latter method, the result is that the denture loses some of its original beauty.

The denture is reinserted in the patient's mouth, and the upper denture is relined. After a few days the occlusion is checked, adjusted, and if necessary, the occlusion is milled in. The patient is now comfortable and needs to be seen only as discomfort occurs. Sometime later, the denture is relined to keep pace with alveolar healing.

RESULTS

The foregoing description summarized the procedure followed for forty-one patients. The patients' ages ranged from 21 to 62 years. The majority have been in excellent health, a few have had hypertension or rheumatic heart disease. In some cases the operation has been specifically recommended by the patient's physician. In all cases, the procedure has been undertaken only with full approval of the examining physician.

The advantages to the patient are:

1. Healing is usually uniform and rapid (Fig. 17). Reasons for this favorable result are: (a) The surgical area is protected from trauma by the denture acting as a splint. (b) The area is maintained in a hygienic and aseptic state. (c) The patient is not upset or debilitated by a series of minor surgical operations, as is the case with the usual procedure. (d) The operated area is not traumatized by injection of anesthetic solutions with vasoconstrictors rendering the area ischemic

during the operation and for several hours after. It is generally conceded that local anesthesia interferes with normal bleeding, clotting, and healing.

2. There is no prolonged period of gradual debilitation due to increasingly impaired function of the masticatory apparatus.

3. There is no alteration of appearance due to muscular changes in the face. This is a very important psychosomatic consideration.

4. The vertical dimension, centric relation, and occlusal relationships are retained exactly as they were prior to extraction of the teeth when it is desirable.

5. The patients transition from natural to artificial dentition is easily accomplished as they have never been without a full complement of teeth.

6. Temporomandibular joint changes are not likely to occur.

Fig. 17.—Four days after the operation and insertion of the denture the tissue is healing nicely. The area has been protected by the denture from the time of the extraction.

7. The condition of the alveolar ridges of patients treated by this technique, compared with those done by more conventional methods in the dental office is interesting. Those who have had immediate dentures appear to have little resorption and retain rounded and well-contoured ridges, while those done in the dental office have the usual marked changes. A possible explanation is continued functioning of the oral mechanism. Those who have been "left to heal and resorb" may undergo disuse atrophy.

SUMMARY

Full-mouth extraction with immediate denture insertion under general anesthesia in one operation is the procedure of choice in the routine management of patients needing full-mouth extractions. Close cooperation with the patient's physician is essential. Anesthesia must be administered by a qualified anesthesiologist and the operation performed only in a well-equipped hospital.

Anesthesia for full-mouth extraction should be performed only under endotracheal, carbon dioxide absorption technique. The anesthetic agents, their adjuncts, and the preanesthetic medication should be individualized for each patient after thorough preanesthetic evaluation. The operation is safe when the conditions outlined above are followed carefully. This type service should be available to all patients who desire it and are physically fit for it. Experience indicates dentists and patients will find the procedure practical and economically sound.

The operations described in this report were performed at the Dow Hospital, Freeport, Texas. The authors hereby acknowledge the valuable cooperation and assistance given by Dr. Mark E. Thompson, Administrator, and Dr. Ralph E. Gray, Chief of Surgery at the Dow Hospital. Thanks are also extended to Dr. Sumter S. Arnim, Professor of Pathology, University of Texas Dental Branch, Houston, Texas, for his assistance in preparation of this paper.

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110 This Way
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SURGERY AND PROSTHESIS IN JAW RECONSTRUCTION

MILTON T. EDGERTON, JR., M.D., AND JAMES E. PYOTT, D.D.S.

Baltimore, Md.

Location: Johns Hopkins Hospital Surgical Clinic

Time: June 6, 1951

Case 1. History No. 570613.—A 27-year-old, married colored woman presented herself with a four-months' history of a painless enlarging mass of the right upper jaw (Fig. 1, *A*). The present illness began with pain in the region of the right upper first and second molars. These were extracted by her local dentist without relief. There had been no bleeding, headache, nasal obstruction, or visual symptoms. Laboratory studies showed a homogeneous radio-opacity in the region of the right antrum, with no evidence of extension into the orbit. Serum test for syphilis was negative; blood chemistries including calcium were normal. The diagnosis was ossifying fibroma with possible sarcomatous degeneration.

DR. MILTON T. EDGERTON: The possibility of malignant tumor here with the definite involvement of bone precluded any use of roentgen-ray therapy as a curative measure. The clinical picture was very similiar to localized Paget's disease of the maxilla, and a high percentage of such patients will ultimately show a sarcomatous change. The absence of orbital involvement makes it possible to remove this type of lesion surgically with very minimal permanent deformity. There was definite evidence, however, of involvement of the pterygoid plates and malar bone, and we thought it therefore unwise to attempt removal of the tumor without an external incision. The right cheek was reflected by an incision splitting the upper lip and carried around the nose up to the inner canthus, and the tumor was removed with the aid of osteotomes (Fig. 1,*B*). A skin graft was then taken from the thigh and immediately applied to the inner surface of the cheek, pterygoid fossa, and floor of orbit (Fig. 1, *C*). We have found that this prevents contracture and later deformity. The cheek was then resutured over an iodoform gauze (Fig. 1, *D*). Ten days after operation the pack was removed and the previously prepared dental prosthesis was inserted (Figs. 1, *E,F,G*). The patient was then ready for discharge and has had no difficulty with either speech or eating since operation.

DR. JAMES E. PYOTT: The upper jaw in such cases proves very suitable for prosthetic restoration because of its normal lack of mobility. When the soft

From Department of Plastic Surgery, Johns Hopkins University, and the Johns Hopkins Hospital, Baltimore, Md.

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palate is not involved by tumor, a light acrylic prosthesis gives an almost perfect speech result. Such a prosthesis may even by worn by patients with edentulous upper jaws.

DR. EDGERTON: The surgical reconstruction of the upper jaw is quite feasible, but it requires several plastic operations over a number of months, and the ultimate result to the patient is little if any better than that offered by a simple prosthesis. The patient's tumor was not epithelial in origin, and we do not feel that a neck dissection was indicated in the absence of cervical lymph-node enlargement.

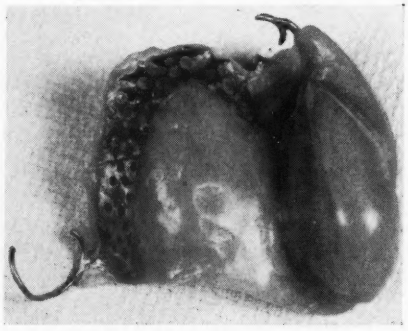

Fig. 1G.—Final hollowball acrylic obturator. Retention is by means of gold clasps for teeth and saddle casting.

Case 2. History No. 486044.—The patient was a 31-year-old white woman who presented herself with a nine-months' history of a tender lump near the right angle of her mandible. This has caused the spontaneous loosening and loss of the second and third right lower molars. The right side of the lower lip was numb. There had been no ulceration within the mouth, and the patient had lost no weight.

Roentgenograms of the mandible showed a rarified lesion involving the angle and ramus. The preoperative impression was adamantinoma.

DR. EDGERTON: As with most jaw tumors, bone involvement is a primary indication for surgical treatment. The extraoral approach has proved to be much more satisfactory than the intraoral route. A low cervical incision was made in the right neck, care being taken to preserve the lowest branch of the facial nerve. The tumor was seen to be contained within the cortex of the mandible and was removed with an adequate margin (Fig. 2,*A*). The pathological report showed this to be a myxangioma (Fig. 2,*B*). A section of oral mucosa had to be removed, and the wound was then closed in layers with drainage. Jaw fixation was maintained by means of a guide plane (Fig. 2,*C*) until all edema had subsided. We then replaced the removed segment of mandible by means of a costal cartilage and rib graft, fashioned so as to reconstruct the temporomandibular joint (Figs. 2,*D*,*E*). In this case, immediate bone grafting was thought not advisable, because of the necessity for opening the oral cavity on removing the

Fig. 1 (Case 1).—*A*, Twenty-seven-year-old patient with bony enlargement of the right side upper jaw. The molar teeth had been extracted by a local dentist. *B*, Specimen removed to show right maxilla including half of palate and right antrum. *C*, Surgical exposure. Skin graft taken from thigh may be seen sutured into position on inner surface of the cheek, extending back to the line of the pterygoid fossa. *D*, Method of closure of cheek. *E*, Obturator in position in mouth. Dental compound extended to close all open areas. After several adjustments, a hollow-ball obturator is fitted to the surgical defect. *F*, Patient, two weeks after operation. The prosthesis is in place. Speech and swallowing are normal.

Fig. 2 (Case 2).—*A*, Tumor of left mandible being removed through a cervical incision. *B*, Gross specimen of myxangioma of left angle and ramus of mandible. *C*, Guide plane shown in position after operation on right side of jaw. Ivy loop temporarily used on left side. Jaw thus held in mid-line. *D*, Same incision has been used to insert a composite graft of rib and costal cartilage to reconstruct left mandible. *E*, Postoperative front view showing symmetry of face.

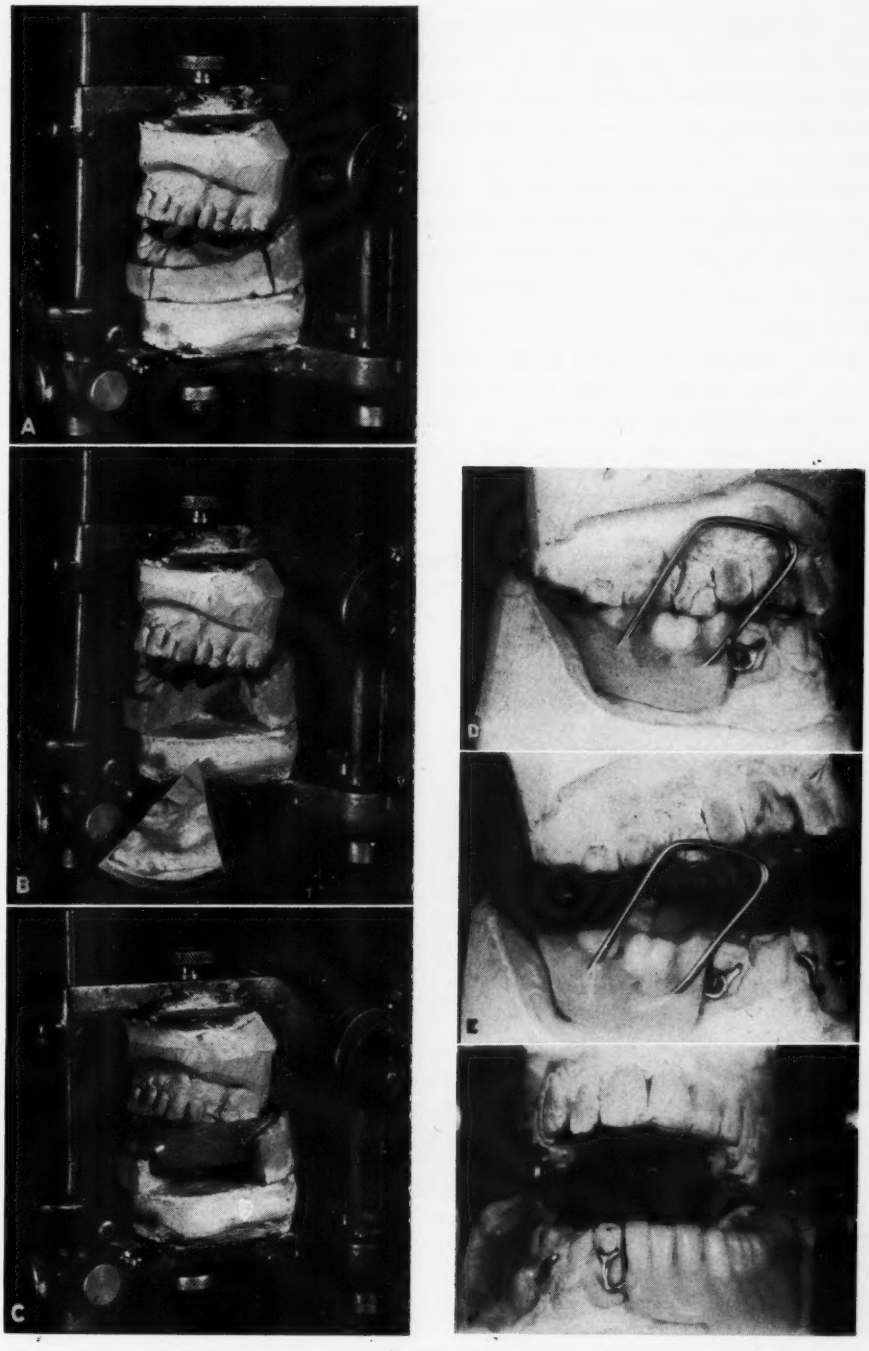

Fig. 3.—*A*, Master casts of jaws in occlusion showing area to be removed from mandible. *B*, Showing area cut from cast that is to be removed surgically. *C*, Splint and guide plane that were inserted after surgical removal of part of mandible at time of operation. *D*, Guide plane in position with mouth closed. *E*, Same patient with mouth open to show sliding action of metal arm against upper teeth. *F*, Front view of guide plane. It may be seen that length of metal arm is limited only by depth of buccal sulcus.

tumor. We have found it most important to maintain moving vertical stabilization of the mandible during the period between tumor removal and bone-graft replacement. If a guide plane is worn for several months, while the soft tissues stabilize, it can often be removed and still keep good jaw position.

Dr. Pyott: When one side of the lower jaw is removed surgically, in a patient possessing the normal complement of teeth, the guide plane is probably the simplest and most useful dental means of maintaining position of the remaining jaw. It may often be combined with a splint of acrylic that fits down into the space left by removal of the mandible (Figs. 3,*A,B,C*). It is frequently desirable to attach this guide plane into position at time of operation. Figures 3,*D,E,F* show the guide plane on the model. If the resection is posterior to the bicuspids, the guide plane can be of the fixed type and inserted before operation, or intermaxillary wires and rubber-band traction can be used to retain normal jaw position.

Fig. 4.—Guide plane and prosthesis used to fill in resected area and maintain normal vertical dimension and position.

Dr. Edgerton: When one has to resect the mandible in an edentulous patient, the use of a guide plane is not possible. In such cases, we have used either immediate replacement of the mandible by means of stainless-steel bars, or we have applied a modified Haynes apparatus externally to the maxilla and mandible and thus created an extraoral guide plane.

DR. PYOTT: The building up of contour by an intraoral prosthesis usually requires adequate remaining teeth for attachment of the prosthesis, and replacement of oral mucosa to allow lateral movment of the cheek. No dental restoration can overcome a tightly contracted scar. Figure 4 shows the upper and lower prostheses utilized in a patient who had a massive resection of the mandible for adamantinoma. Figure 5 shows a patient with a primary carcinoma of the soft palate and the type of prosthesis used to replace the soft palate following surgical resection. The problem of velopharyngeal closure here is similar to that encountered in some cleft-palate patients. The use of a prosthesis is of utmost importance in the successful care of many patients who have had oral and facial cancer removed or destroyed. Patients who have suffered cosmetic disabilities must be returned to society as nearly normal as possible; i.e., their jaws or remaining parts of bone must be retained in a position close to physiological function by aid of a prosthetic appliance, skin or bone graft, or other reconstructive surgery, if necessary. Each case presents a problem of its own. It is essential that a definite routine be followed in all cases, with co-operation between surgeons, radiologists, and prosthodontists. The following basic rules must be followed to produce satisfactory results.

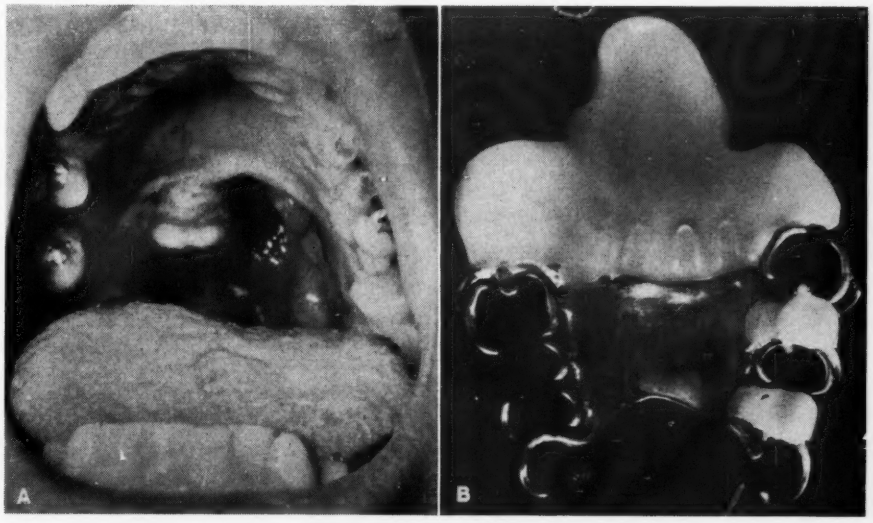

Fig. 5.—*A*, Area of soft and hard palate involved by primary adenocarcinoma. *B*, Obturator replaces resected palate and maxilla. Cast gold in hard-palate area. Clasp retention. Acrylic used as obturator in region of soft palate.

1. Upon admission to the hospital a full-mouth, and extraoral, roentgenograms are made. Impressions of the maxillary and mandibular ridges, the surrounding tissues, and remaining natural teeth are taken with any good impression material, such as the hydrocolloids, alginates, or plaster; master casts are poured in artificial stone and mounted with correct centric relation on an articulator.

2. In cases involving lower jaws, the ends of the mandibular fragments should be held apart mechanically, in the normal position maintained by the muscles and intact bony arch before surgery. The normal occlusal relation of the remaining teeth must be maintained by adding artificial teeth, if necessary, to the appliance.

3. When bone and soft tissue are surgically removed, in cases involving the upper jaw, obturators, stents, and Gunning splints are made for protection of new tissues and open areas during healing. These appliances also keep food and liquids from passing through the nasal orifice and permit the adequate consumption of food during convalescence.

4. Finally, a finished prosthesis permanently maintains the normal facial contours and the normal function of the jaws. Sometimes these appliances may include buccal guide planes, space retainers, hollow-ball and solid obturators, and sections replacing lost parts and lost teeth.

SUMMARY

DR. EDGERTON: It might be said in summary that the surgeon treating tumors of the upper or lower jaw today will find that the help of the prosthodontist is an invaluable aid in acquiring maximum functional results. The particular anatomical requirements of each case must dictate whether the primary reliance should be on prosthetic or living-tissue restoration. Reconstruction with living tissue yields an oral cavity that enjoys better hygiene and does not depend on the permanent retention of teeth. However, this often requires prolonged or elaborate surgery, which may not be reasonable in view of the particular patient's age or his special needs.

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RELATIVE ABILITIES OF NATURAL AND ARTIFICIAL DENTITION PATIENTS FOR JUDGING THE SWEETNESS OF SOLID FOODS

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DURING MASTICATION of foods a sequence of events must take place quickly in order that the maximum discrimination of the taste levels can take place. The food must be pulverized, mixed intimately with saliva, and carried to the site of gustation. These events must happen rapidly if the maximum sensation is to be experienced, since within a few seconds after chewing begins, the subject decides that the food is ready for swallowing and removes it from the taste area. It is logical to expect that the rate of pulverization of the food by mastication, the rate of salivary secretion, and the time food is kept within the mouth will all determine whether the sensitivity of taste buds is fully utilized. There is reason to expect that some loss of taste might result from the proved inadequacy of masticatory ability among denture wearers.[1] It has been shown that poor efficiency in mastication does not induce a denture wearer to chew his food for a longer time, but merely to swallow coarser food.[2]

Three articles have been found relevant to the present investigation. Chambers[3] described two patients with loss of taste who were relieved of this complaint by preparation of "roofless" dentures. Strain[4] also gave consideration to the question of whether or not denture bases cover gustatory areas, and seemed to reach a conclusion that dentures should not have an adverse effect. Neither of these investigators obtained information on the degrees of impairment in taste sensation among denture wearers. The study by Laird[5] was quantitative, but was concerned with preference for sweetness of pineapple juice rather than the ability to perceive the flavor of food. He observed no difference between taste preference of full denture patients and natural dentition patients.

The last two articles were concerned only with taste perception of substances in solution. Mastication was not required. The goal of our studies was to use

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solid food as a test material and to employ psychophysical techniques[6] which had been shown to be applicable to a problem involving artificial and natural dentition patients.[7] Sugar was selected as the taste stimulus and cookies as the solid food in which sugar would be varied. The purpose was to determine whether denture wearers as a group can perceive subtle differences in flavor of solid foods that persons with natural dentitions can appreciate.

PREPARATION OF TEST FOODS

The following ingredients were common to all batches of sugar cookies prepared:

½ cup shortening
1¼ cups flour
¼ teaspoon salt
1½ teaspoons baking powder

Four different batches were prepared with 6, 7, 8, and 9 ounces of sugar and baked at 350°F. The preliminary trials showed that the cookies with higher concentrations of sugar were harder in texture. These differences in hardness were eliminated by changing the baking time from the usual fifteen minutes required by the recipe to seventeen, sixteen, fifteen, and fourteen minutes, respectively. This change reduced the possibility that the subject would judge differences among the cookies on the basis of hardness. The finished product was about one-quarter of an inch thick and was cut into eight morsel sized pieces with a one-inch circular saw.

ADMINISTRATION OF TEST

The subjects were seated so that they could not observe which morsel was selected by the experimenter. The experiment was conducted in two parts, one with and the other without a time limitation on the judgment. The subject was given the following instructions for Part I. "There are four different cookies here; two of them are sweeter than the other two. Each time you are given a piece of cookie you are to tell me whether it is one of the 'more' sweet or one of the 'less' sweet group. You will be given a sample of each one before the test begins in order that you may get an idea of how each cookie tastes."

The following phrase was added for Part II: "As soon as I say stop, tell me which group the cookie belongs to even though you may have to guess."

In Part I the experimenter recorded the patient's verbal response and the time required to reach his decision; in Part II the verbal response at the end of ten seconds was recorded. Part II was given prior to Part I in alternate subjects in order to balance any learning or practice effects. The presentation order of cookies was 1432, 3124, 4213, 4231, 2314, 3421, 4312, 3214. The preliminary trial was in the order 4132. In all instances the figure 4 applies to the cookie having 9 ounces of sugar per batch whereas the figure 1 applies to the batch containing 6 ounces.

This procedure was adapted from the pyschophysic method of single stimuli[8] which permits the patient to make judgments eight times on each level of sugar.

Fifteen denture patients and fifteen persons with natural dentitions were studied which provided 120 judgments on each level of sweetness for both the denture wearer and the natural dentition person.

RESULTS

The results with natural dentition persons are presented in Fig. 1. If the patient judged that the cookie was one of the sweeter group, his answer was marked "plus." The percentage of plus answers was plotted on probability paper for each level of sweetness. The percentage of plus answers without time restriction is shown for each level of sweetness by an "X"; the data for a ten second time restriction are shown by "O's." These points for the two conditions are near each other on Fig. 1, indicating that the precision of judgment among natural dentition patients is unaffected by the ten second time limit. Since natural dentition patients needed only six seconds on the average for each judgment, the ten-second limit was no real restriction.

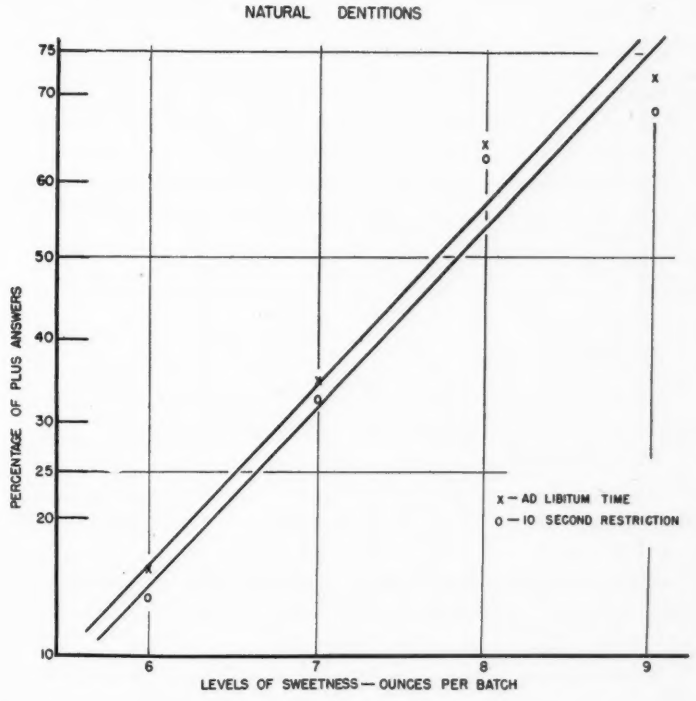

Fig. 1.

The lines on Fig. 1 were drawn by inspection and checked by the method of least squares. A steep line indicates precision in judgment, whereas a horizontal line suggests that the subjects are merely guessing and cannot really distinguish any differences. The slopes of the two lines are essentially the same, indicating that the patients had the same precision of judgment, with and without the time limitation. From these lines, the threshold for sensitivity was calculated by reading off levels of sweetness at the 25 and 75 per cent intersections. The

difference between these levels divided by two represents the threshold. It amounts to 15 per cent of the mean sugar concentration, and in practical terms indicates that a difference of 0.27 Gm. per morsel would be differentiated correctly three out of four times.

Denture patients were found to be less capable, on the average, than natural dentition patients. The results for the fifteen denture patients are presented in Fig. 2 by solid lines. The mean line for the natural dentition patients is superimposed and indicated by dashes. When there was no time limit, the artificial dentition patients had an average threshold amounting to 30 per cent or 0.54 Gm. per morsel. On the average they required fifteen seconds to reach a judgment which is significantly different from natural dentition judgment time at $< .01$ l.o.c. as determined by Cochran and Cox's method for samples having unequal variances.

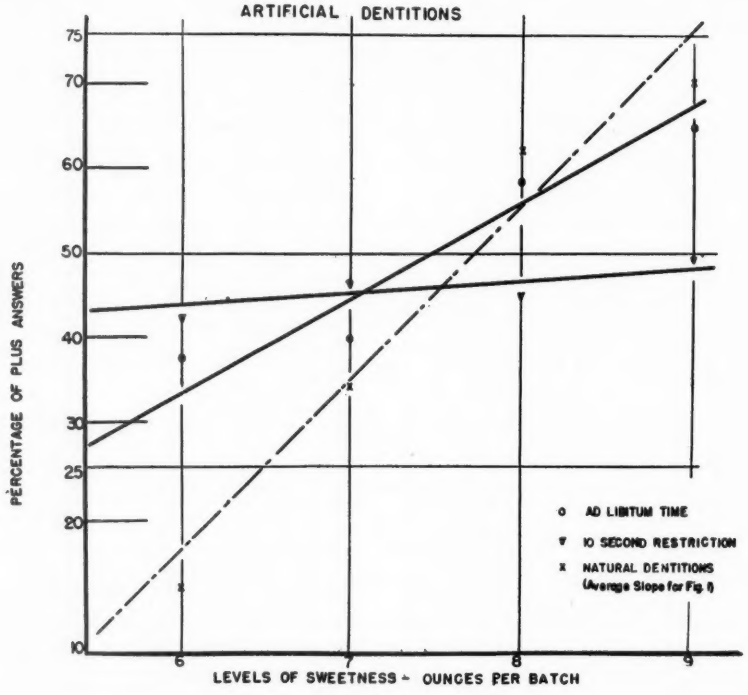

Fig. 2.

Even though the artificial denture patients took over twice as much time to reach a decision, their average discrimination was only half that of natural dentition patients.

Restriction of the judgment time to ten seconds had a pronounced effect on the precision of judgment of artificial dentition patients. The solid line marked with triangles is nearly horizontal, indicating that for this range of sweetness, the patients were guessing most of the time. There is a definite slope to the line, however, which permitted an extrapolation to the threshold of 2.3 Gm. per morsel

to be calculated. By this criteria the artificial dentition patient is handicapped in comparison with the natural dentition patient. If the average full denture patient was asked to judge sweetness and allowed ten seconds per morsel, he would theretically be mistaken one-fourth of the time in trying to distinguish between a cookie having no sugar and one containing twice as much as the sweetest one presented to him in this study.

There may be some question as to which of these two conditions, with or without time restriction, better represents the normal conditions under which food is consumed by the artificial dentition patient. It is our opinion that the test with ten-second limitation approximates more closely the conditions at meal time than would the unrestricted test. It has been reported[1, 2] that low masticatory efficiency does not cause full denture patients to chew food for a longer time. These persons would be expected to consume cookies as quickly as would natural dentition persons. Hence it is probable that the denture patient requires about eight times as much difference in sweetness as does the natural dentition person in order to detect differences with the same degree of certainty.

There are two explanations of this difference between thresholds. The poor chewing efficiency of full denture patients may hamper pulverization of food, and slow down the solution of sugar in saliva. If manipulation of food is impaired, the full denture patient may be less able to transport the saliva and food bolus to the taste areas, or to clear his mouth of food between morsels. The pulverization of food particles, of sugar into saliva, and of dissemination of saliva to the taste buds may be affected. If there is a decrease of salivary flow among denture wearers,[9] it may decrease the rate of solution of sugar or its distribution to the taste buds.

SUMMARY

A solid food for psychophysic tests on detection of differences in sweetness was prepared by modification of a standard batch of sugar cookies. A group of 15 natural dentition patients and 15 artificial dentition patients, with approximately matched ages, were compared as to differential threshold using a special adaptation of standard psychologic procedures.

The natural dentition persons averaged six seconds in order to reach a decision when concerned with sweetness of the test foods, and their threshold was not affected by a limitation of the time of judgment. The threshold was 15 per cent of the average sugar concentration of the batches. The denture patients averaged fifteen seconds for reaching the judgment, and had a threshold of 30 per cent. When they were limited to ten seconds reaching the judgment, the threshold was over 100 per cent.

These results indicate that artificial dentition patients as a group apparently cannot perceive and enjoy subtle differences in the sweetness of solid food that can be appreciated by persons with natural dentitions.

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PERSONALITY FACTORS RELATING TO OVERADAPTATION TO DENTURES

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JUST AS IN DEALING with the human element in any of the healing arts, we find a wide variation in the ability of people to adapt to dentures. A certain group are able to adjust so well that considerable damage is done to the supporting tissues because they do not seek service. Some will even claim that dentures considered by the dentist as somewhat less than satisfactory are better than their natural teeth, while others will wear faulty dentures for many years without having them serviced. In many of these cases, the vertical dimension and centric relation have long since been lost because of tissue change. Satisfactory adaptation of the bases to the tissue is nonexistent. These patients often come to the dentist's attention only because they have broken their dentures and wish to have them repaired, or because the tissue has broken down so badly their pain threshold has finally been reached.

One of the primary objectives in denture construction is the constant preservation of the tissue that remains, rather than the meticulous restoration of what is missing.[1] Without the proper servicing of dentures the accomplishment of this becomes improbable. Patients who overadapt to dentures will usually present more than average loss of the supporting structures. Although the immediate prognosis for these patients is somewhat favorable, the long-range outlook is not as promising.

EXAMINATIONS

The case studies which follow present illustrative findings abstracted from medical examinations, family histories, and psychologic tests. The methods used were similar to those reported in another article, in that an attempt was made to account for the basis of the dental difficulty by psychologic methods. For a more complete description of the methodology, the reader is referred to this article.[2]

The opinions and conclusions contained herein are those of the writers and do not necessarily reflect the official views of the Department of the Navy or of the Department of Defense.

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CASE REPORTS

CASE 1.—A retired naval chief petty officer, aged 55 years, wears complete dentures. Dental examination revealed the centric relation to be incorrect, and the adaptation of the maxillary denture to the tissue unsatisfactory, with poor retention. The patient, however, seemed to be satisfied with these dentures and did not wish to have new ones made or to have the present ones serviced, even though he would have to pay no fee for the treatment. He came to the dental clinic to have a broken tooth replaced.

The medical history revealed chronic gastrointestinal disturbances which started as a "nervous acid stomach" about fifteen years ago. Consequently he spent considerable time in hospitals and finally received surgery for ulcers. He was eventually retired from the Navy with a medical survey and pension.

While undergoing treatment for the ulcers, his teeth were removed to eliminate possible foci of infection, and immediate dentures were constructed for him. He wore these satisfactorily for six or eight months. The dentures he now wears were then constructed, and although they are not satisfactory from a physiologic standpoint, he has been completely satisfied with them for about seven years.

Reviewing significant factors in his personal and social history, we find evidences of strict early parental supervision, and while still quite young his mother became ill; consequently he was required to live in an orphanage. He has earned his own living since he was twelve. At one time in his naval career he was demoted in rate for disciplinary reasons. More recently he was discharged from a government job for doing unsatisfactory work and for not being able to get along with his boss. He has been married for eighteen years and has no children.

Psychologic examination revealed the patient to be a very unstable individual with unresolved conflicts of long standing. Many of these were no doubt momentarily held in check during his long illness, but at present it appears his methods for dealing with his conflicts are not adequate, and that his future mental health is being threatened. Still predominant in the personality structure are several strong unresolved conflicts from his earlier years. These seem to be centered around intense feelings of hostility against his father, a closeness to his mother, and rivalry with a sister. There are actual unconscious death wishes toward the father and further indications that all is not well in his present marriage, although he states that he is happily married. Pervading the psychologic tests are overly developed guilt feelings, and a theme of evaluating most of his social relations in terms of monetary worth. Strong guilt feelings and unresolved and unchanneled hostile and aggressive impulses make him susceptible to a need for external controls, since his own ego is so inadequate he fears his uncontrollable impulses. The ego itself seems to be in a state of disintegration, so that the very integrity of his personality is at stake. Fears of such a disequilibrium become somaticized and are manifested in his fear of bodily harm. Clinically, he is a very outgoing person who tries to meet his problems and arrive at a solution, no matter what price he must pay, rather than retreat from the issue.

Significance to the Dentist.—This patient fears the discomfort and possible pain of having to adjust to new dentures and therefore denies to himself that anything is wrong with his present dentures.

He has more than average difficulties with authority, illustrated by aggressive feelings toward his father and manifested in his daily life; for example, by disciplinary action taken against him while on active duty in the Navy and difficulties in civilian jobs. This may lead to his acceptance of dentures somewhat less than

satisfactory and avoidance of proper service of the dentures. Avoiding possible difficulties with the dentist, who to him represents authority, results in denial of the unsatisfactory dental condition.

CASE 2.—This patient, aged 19 years, is on active duty in the Navy. He wears complete maxillary and mandibular dentures. The centric relation of these dentures is incorrect and the adaptation to the supporting tissues is not satisfactory. The dentures are somewhat unstable because the posterior teeth of both the maxillary and mandibular dentures were set too far buccally. The mucous membrane supporting the dentures was inflamed when this patient was examined. He has been wearing the replacements for over one year and states that "he wouldn't trade them for his natural teeth."

The patient comes from a broken family in which the mother died when he was 8 years old. The father remarried and the patient states that since the marriage the father has become "grouchy." The stepmother is not well liked and the patient stated, "My stepmother always tried to make trouble between my father and me." She is further characterized as continually "complaining about everything."

The patient was active in sports in high school, having won several awards for his athletic achievement.

In describing himself, the patient declared, "I think I am one of the most happy-go-lucky people a person will ever run across. I am easy going and get along very well with all the people I know."

In discussing what kind of a person he wanted to be, the patient stated, "My achievement is that I am healthy and able-bodied. I am willing to fight for what is right to keep this a free and democratic country. I want to be a person that is looked upon with respect and not pitied. I want people to like me and give me a place in their life as a good friend not an enemy. I think I have a big part of that whipped because I have a natural ability of talking to people."

Psychologic examinations revealed the personality to be characteristic of an individual in mid-adolescence, still absorbed in growth and change, and still in turmoil. The patient shows strong indications of impulsiveness and lacks adequate controls over these impulses. He has a large amount of energy which is directed outward toward his environment. This can cause a high degree of emotionality in his interpersonal relations. Of long standing in the personality structure are unconscious excessive feelings of inferiority and inadequacy, while he attempts to keep in check by his outgoing nature and desire to be liked by others. When these measures fail, he resorts to a withdrawal from social stimuli—into daydreaming and immature fantasy—rather than meeting the situation directly.

Significance to the Dentist.—Partially resulting from his feelings of not being accepted in his home life, one of the primary motivating forces developed in this patient is to be well liked and accepted by others. To him, any physical illness represents disgrace or loss of prestige in the eyes of his associates. It thus becomes clear why he denies to himself the existence of his denture difficulties. Underlying inferiority feelings become manifest in his overdeveloped desire to be well liked. He, of necessity, had dentures constructed originally, but seeking further service from the dentist would be a threat to his imagined standing in the eyes of others. The denial of difficulties thus stems from factors in the personality of which the patient is not aware.

CASE 3.—This patient is 46 years old, and a chief petty officer in the Navy. He has been a denture patient for over twenty years, starting with partial dentures. The first complete set of dentures was satisfactory, and he wore them for fourteen years. Although his second set of complete dentures was unsatisfactory, he has worn them for the past three years. When he reported for treatment his maxillary ridge was completely broken down in the anterior region (Fig. 1) and in the region of the tuberosities. Surgery was necessary to remove the pendulous soft tissue which was as much as seven millimeters thick (Fig. 2). Complete dentures were then constructed and he is wearing them satisfactorily.

Fig. 1.—Denture-bearing tissue broken down in the anterior region because of patient's overadaptation to unsatisfactory dentures. Surgery was necessary to prepare the mouth for new dentures.

Fig. 2.—Surgically removed soft pendulous tuberosities. These tuberosities were broken down to a depth of 7 mm.

Psychologically, this patient has a highly rigid and inflexible personality with little potentiality for adaptation or change. He is overconforming in his social attitudes and in meeting his problems; he attempts to change circumstances to

conform with his own personality. There is a considerable amount of anxiety present, and feelings of inferiority and inadequacy are predominant in the personality. Indications are that he has made a somewhat inadequate social and vocational adaptation, or at least feels inferior in these areas. In his daily life, he tends to accept the most obvious elements in his environment rather than exert energy creatively.

Over-all, he is an individual who is outgoing, inadequate as he appears, and spends little time in daydreaming or in fantasy activities. He does show potentialities for emotional warmth with other people, perhaps developed as a method for overcoming his inferiority feelings.

Significance to the Dentist.—Because of this patient's inflexibility and inability to adapt to change, he denies to himself that anything is wrong with his unsatisfactory dentures. In this manner he may possibly attempt to avoid having to adjust to a new set of dentures.

SUMMARY

For a number of reasons, some patients overadapt to dentures. Because these patients are not likely to seek adequate service, damage to the supporting structures is to be anticipated. A primary reason found in the examination of a group of these patients was a conscious denial to themselves that an unsatisfactory condition existed. Several explanations are suggested for this denial, all of which seem to be related to an attempt to avoid painful anxiety. The findings presened in this article support those found in another study not directly concerned with dental problems.[3]

One patient had considerable difficulty with authority relations and in an effort to avoid difficulties with the dentist, who, to him, represented authority, denied that anything was wrong with his unsatisfactory dentures. This patient also revealed a strong fear of bodily pain or injury.

Another patient had an overdeveloped desire for good health, and in order to avoid the anxiety that might be engendered by varying degrees of ill health, he denied that an unhealthy condition existed with regard to the dentures.

When threatened by possible change, overwhelming anxiety resulted in the third patient. Because of his inflexibilty and inability to adapt to change he denied that anything was wrong with the dentures, thus momentarily avoiding the precipitating anxiety associated with having to have new dentures constructed and adjusting to them.

Acknowledgment is made to Miss Adeline Poltrack and Miss Jean Gallup who administered the Rorschach tests.

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TIN-FOIL SUBSTITUTE: WARPAGE AND CRAZING OF ACRYLIC RESIN

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THE PURPOSE of the study was to investigate some of the conditions causing surface and internal stresses of acrylic resin, and to relate these conditions to the practical application of acrylic resin as a denture base material.

PROCEDURE

The test specimens for the initial experiments were made on a steel die (Fig. 1). Stone duplicates of the master model were made in Coecal dental stone (Coe Laboratories, Inc.) using Duplikrome duplicating material (Ransom & Randolph Co.). The stone models so obtained had an extremely smooth surface. The maximum variation in any dimension between the master die and the stone model was two-tenths of one per cent.

Acrylic specimens were made using the stone models. The thickness of the specimens was kept at 2 to 2½ mm. to simulate denture conditions. The wax-up, wax elimination, and packing were done following standard dental procedures. The investment material was dental plaster. The specimens were processed at 160° F. for nine hours. Tin foil and tin-foil substitutes† were used as mold lining materials.

These materials were used under the following conditions:

1. Tin foil on the stone model and on the plaster investment.
2. Tin foil on the stone model, tin-foil substitute on the plaster investment.
3. Tin-foil substitute on the stone model and on the plaster investment.
4. Tin-foil substitute on the stone model, tin foil on the plaster investment.

Examination of the specimens revealed that acrylic resin processed against tin-foil substitute showed blanching and fogging and, in some cases, adherence of plaster particles. When sections of these unpolished specimens, processed against the tin-foil substitute, were subjected to acrylic monomer for thirty seconds, crazing was produced.

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†Seal-X (Cosmos Dental Products, Inc.) was used as a representative for the group of alginate film forming tin-foil substitutes. Experiments were also conducted using silicone type rub-on pastes and Cellophane. These products rendered the same results, crazing and warpage, as did the alginate. For further information on this particular subject, see Ferguson, Paffenbarger, and Schoonover.[1]

Observation of unpolished and polished specimens under a microscope demonstrated that specimens processed with tin foil on both sides showed no evidence of crazing, while those processed in a mold lined with tin-foil substitute on both sides showed crazing from both the model and the investment surface to a depth of approximately 25 per cent of the thickness from either side. Polarized light revealed the crazing to be in an infinite number of planes. Crazing on the side where the substitute was used also took place in the specimens processed with tin foil on one side and tin-foil substitute on the other.

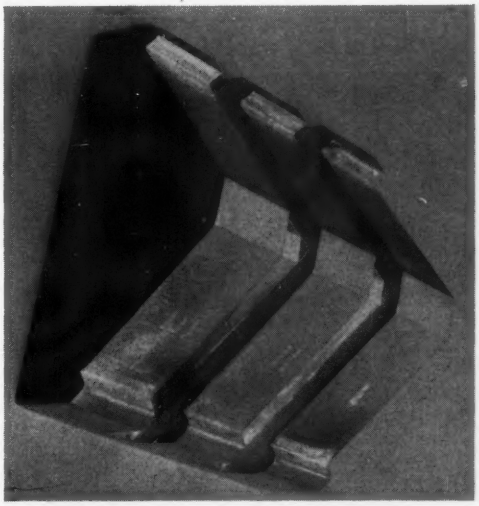


Fig. 1.—Steel master model. Stone duplicates of this model were used for the fabrication of acrylic resin specimens.

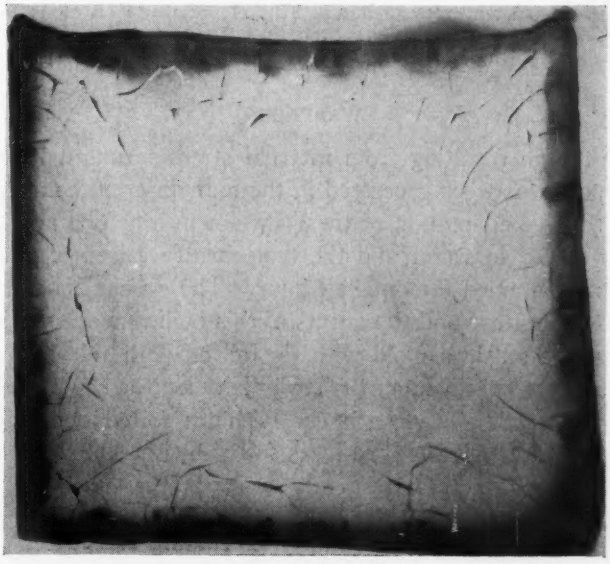


Fig. 2.—Cross section of a clear acrylic resin block, 12 mm. by 12 mm., exposed to monomer for 30 seconds; crazing extends 2 to 3 mm. towards center. The block was processed against tin-foil substitutes.

To further illustrate this penetration of stresses, clear acrylic resin specimens 12 mm. thick and 12 mm. wide were made in molds lined with tin-foil substitute. A section was cut from each specimen and the exposed surface was polished. In this way, it was possible to have a surface which had its center 6 mm. from any surface processed against tin-foil substitute. Different tin-foil substitutes were used. After subjecting the specimens to monomer for thirty seconds, crazing took place around the edges of the polished surface, leaving the center portion of the surface uncrazed (Fig. 2). The crazing extended 2 to 3 mm. from the surface edges toward the center. The severity of the crazing increased as the specimens dried.

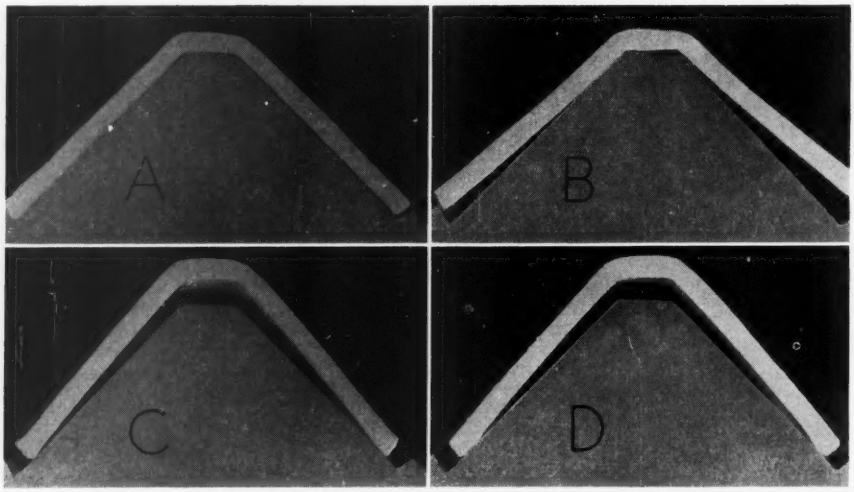


Fig. 3.—Warpage upon boiling of acrylic resin specimens processed with: *A*, Tin foil on stone model and on plaster investment. *B*, Tin-foil substitute on stone model; tin foil on plaster investment. *C*, Tin foil on stone model; tin-foil substitute on plaster investment. *D*, Tin-foil substitute on stone model and on plaster investment.

WARPAGE

To study warpage resulting from internal stresses caused by the use of tin-foil substitute, specimens were processed in the four different combinations of mold linings and the relative adaptation of these specimens was observed. These specimens were then placed in water and the temperature raised to 212° F. and this temperature was maintained for one-half hour. The specimens were then allowed to cool to room temperature and the effects of this boiling were studied (Fig. 3).

Specimens processed in a mold with tin foil on both sides showed no change in the adaptation of the specimen on the steel die or on the stone model upon which they had been processed. The specimens with tin foil on one side and tin-foil substitute on the other, and those with tin-foil substitute on both sides exhibited warpage. The warpage was consistently towards the smoother surface. The flash between the mold halves did not influence the direction of warpage.

Specimens were placed in body temperature water for one week to study the effects of storage temperature on the release of internal stresses. Warpage was

noted in the specimens processed entirely against tin-foil substitute but most change occurred in specimens processed with tin foil on one side and tin-foil substitute on the other. No change was found in the specimens processed with tin foil on both sides.

On the basis of these findings it was decided to repeat the experiments on relative adaptation of the specimen using denture blanks. It was also decided to study the possible relation between relative adaptation and change of weight due to water sorption.

PROCEDURE

Edentulous Dentoform metal models were used as master models. Stone models were produced as described previously.

In order to determine possible dimensional changes occurring during the processing and under various storage conditions, triangular reference marks were engraved in the metal master model. These marks were produced again in the stone models and on the denture blank after processing.

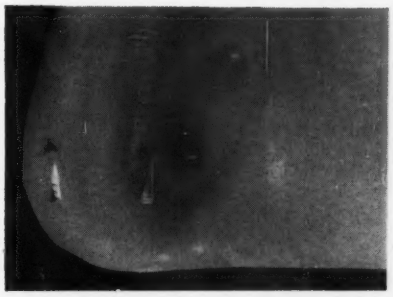


Fig. 4.—Triangular reference marks shadowed and transferred from the metal master model to the stone model and the acrylic resin denture blank. Tin foil .0005 inch reference marks were placed at the time of packing and were used for measuring denture blanks during storage.

Easier and faster orientation of the models under the measuring microscope was obtained by placing triangular pieces of tinfoil, .0005 inch in thickness, on the surface of the acrylic resin at the time of packing, at the location of the tuberosities and at the buccal flanges (in the same frontal plane) (Fig. 4). The latter reference marks were used for the recording of the dimensional changes taking place during storage of the denture blanks.

Sets of four denture blanks were fabricated under the conditions of mold lining previously described.*

The following processing conditions were employed:

1. 160° F. for nine hours; bench cooled for two hours before quenching in water.
2. 160° F. for one hour, 212° F. for one-half hour; bench cooled for two hours before quenching in water.
3. 160° F. for nine hours; quenched in water immediately.

*An alginate type of tin-foil substitute (Seal-X) was used throughout this part of the experiment.

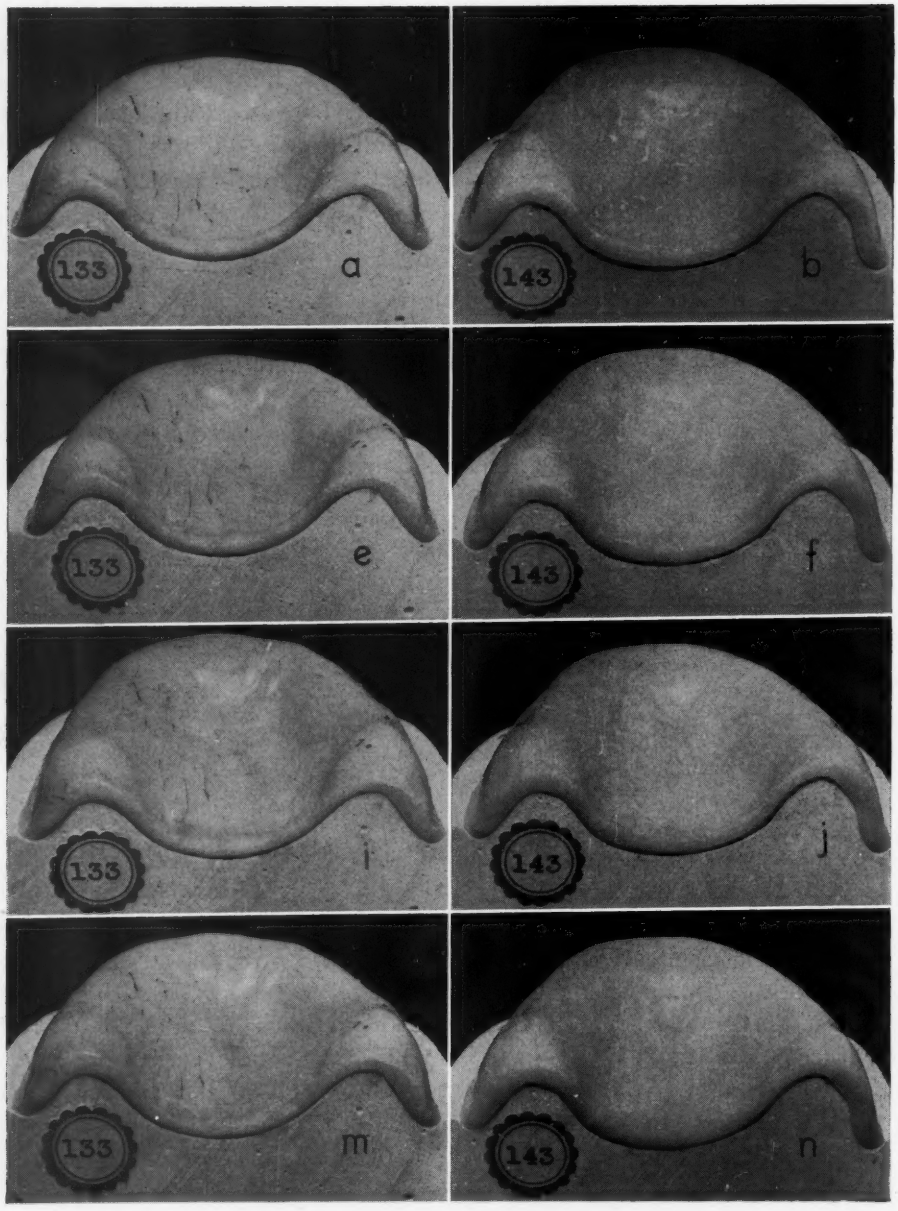


Fig. 5.—Photographic records of acrylic resin denture blanks: 133 series (*a,e,i,m*) processed with tin foil on stone model and on plaster investment. 143 series (*b,f,j,n*) processed with tin foil on stone model and tin-foil substitute on plaster investment. 173 series (*c,g,k,o*) processed with tin-foil substitute on stone model and on plaster investment. 163 series (*d,h,l,p*) processed with tin-foil substitute on stone model, tin foil on plaster investment. *a,b,c,d,* show the adaptation immediately after processing. *e,f,g,h,* show the adaptation after twenty-four-hour storage in water at room temperature. *i,j,k,l,* show the adaptation after additional seventy-two-hour storage in water at body temperature. *m,n,o,p,* show the adaptation after additional seventy-two-hour storage in water at body temperature (one week). No further change could be observed after one month of storage.

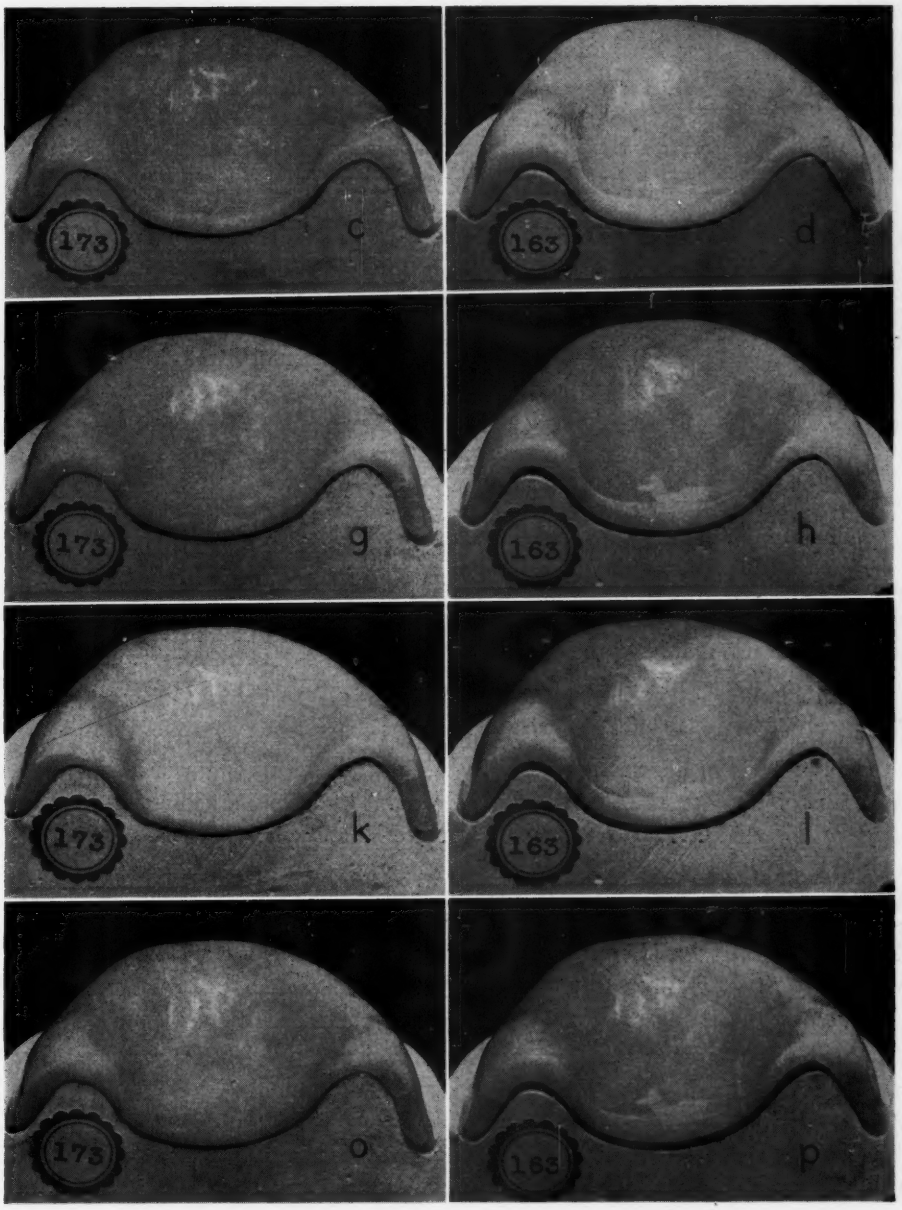


Fig. 5 (*Continued*): (*For legend see opposite page.*)

4. 160° F. for one hour, 212° F. for one-half hour, quenched in water immediately.

Immediately after deflasking of the stone models and the denture blanks, the posterior of the denture blanks were trimmed following a standardized procedure. Immediately following this, photographic records of the adaptation of the denture blanks on the stone models were obtained under as nearly identical photographic conditions as possible. The denture blanks were then measured by means of a measuring microscope. These measurements were taken to establish the distance between the tuberosities and between the buccal flanges. Immediately after the measurements were taken the denture blanks were weighed.

Photographic records, linear measurements, and weight records were again obtained at the following intervals:

1. After twenty-four hours storage in water at room temperature.
2. After additional seventy-two and one hundred forty-four hours storage in water at body temperature (total: one week).
3. After one month of storage in water at body temperature.

After one month's storage, sets of four denture blanks were heated to 150° F. and kept at this temperature for fifteen minutes and cooled slowly. Photographic records, linear measurements, and weight records were obtained at this time, and again after the same denture blanks were heated to 212° F. and maintained at this temperature for twenty minutes, then cooled slowly.

RESULTS AND DISCUSSION

On the basis of observation of sixty-six denture blanks it was found that the adaptation of the denture blanks on their stone models immediately after processing was offected by two factors: lining material and curing cycle.

EFFECT OF LINING MATERIAL

The first photographic record of the denture blanks revealed that in all instances the best adaptation was obtained when tin foil was used as the lining material on both stone model and plaster investment (Fig. 5, *a*).

A slightly poorer adaptation was found when tin foil had been used on the stone model and tin-foil substitute on the plaster investment (Fig. 5, *b*).

Considerable warpage was found in denture blanks processed with tin-foil substitute on both stone model and plaster investment and in those processed with tin-foil substitute on the stone model and tin foil on the plaster investment (Fig. 5, *c* and *d*).

After twenty-four hours, four days and seven days, and after one month storage in water at body temperature, warpage was found to be greatest in denture blanks processed with tin-foil substitute on the stone model and tin foil on the plaster investment. Less warpage was observed in denture blanks processed with tin-foil substitute on both sides, whereas the best adaptation was found in denture blanks processed entirely in tin foil (Fig. 5, *e* through *p*).

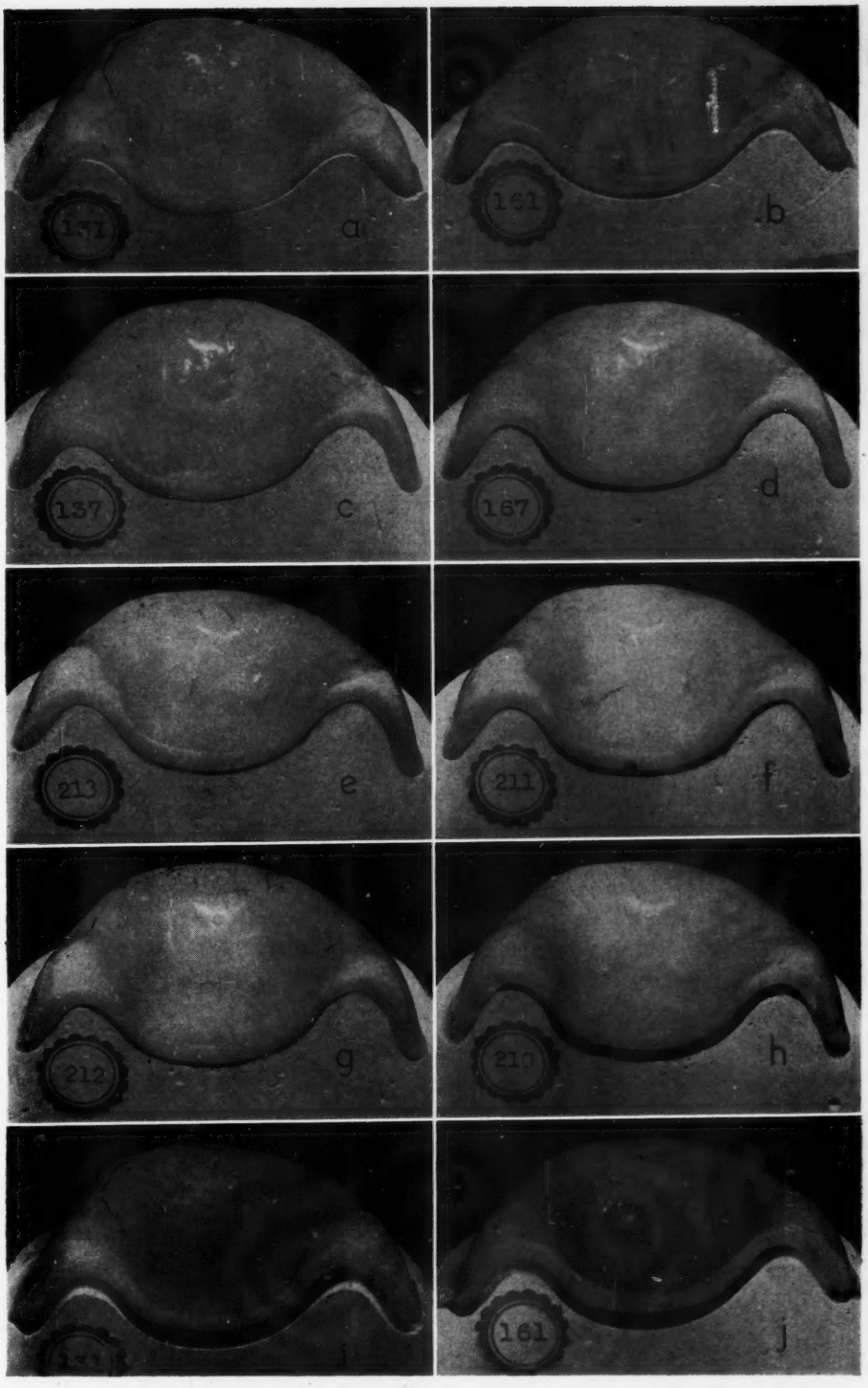


Fig. 6.—Photographic records of acrylic resin denture blanks, illustrating the effect of different processing and cooling techniques, and the effect of boiling test. *a,c,e,g,* and *i,* processed with tin foil on stone model and on plaster investment. *b,d,f,h,* and *j,* processed with tin-foil substitute on stone model, tin foil on plaster investment. *a* and *b,* processed at 160° F. for nine hours, bench cooled for two hours before quenching. *c* and *d,* processed at 160° F. for nine hours, then quenched. *e* and *f,* processed at 160° F. for one hour, then at 212° F. for one-half hour, bench cooled for two hours before quenching. *g* and *h,* processed at 160° F. for one hour, then at 212° F. for one-half hour, then quenched. *i* and *j,* same specimens as *a* and *b,* stored in water for one month, then immersed in boiling water for twenty minutes.

Heating the denture blanks to 150° F. for fifteen minutes did not cause visible change in the adaptation. Immersion for twenty minutes in boiling water resulted in very severe warpage of all four types of denture blanks (Fig. 6, *i* and *j*). The warpage mainly took place during the first forty-five seconds of boiling after which no appreciable change occurred. It was noted upon step-by-step heating of denture blanks that a temperature of 195° F. was required to bring about severe warpage rapidly.

EFFECT OF PROCESSING TEMPERATURE

When denture blanks processed at 160° F. for nine hours (Fig. 6, *a,b,c,* and *d*) were compared with those processed at 160° F. for one hour, then at 212° F. for one-half hour, the latter was found to exhibit more warpage (Fig. 6, *e,f,g,* and *h*). Again, specimens processed with tin-foil substitute showed more warpage than those processed with tin foil.

EFFECT OF COOLING TECHNIQUE

When identical processing cycles were used, quenching of the flask immediately after processing (Fig. 6, *c,d,g,* and *h*) resulted in more warpage of the denture blanks than bench cooling of the flask for two hours before quenching (Fig. 6, *a,b,e,* and *f*). This was most clearly demonstrated in the denture blanks processed with tin-foil substitute on the stone model and tin foil or tin-foil substitute on the plaster investment (Fig. 6, *b,f,d,* and *h*).

LINEAR DIMENSIONAL CHANGES ACROSS POSTERIOR

Several investigators[2-6] have published data using measurements from one tuberosity to the other as an indication of dimensional behavior of acrylic resins for comparative purposes.

Sweeney, Paffenbarger, and Beall[2] used such measurements and correlated them with water sorption.

Skinner and Cooper,[3] Skinner,[4] and Smith[5] also based their conclusions on such measurements, and McCracken,[6] with some reservation, employed this method of comparison for evaluation of autopolymerizing resins against heat-cured materials.

It was found in this study that measurements from tuberosity-to-tuberosity were changing differently than were measurements from flange-to-flange.

A very thorough analysis of 290 measurements taken of 26 denture blanks, and of the actual adaptation of the respective blanks, bears out the conclusion that no relationship could be found between the recorded measurements and the change of adaptation of the denture blanks on their models.

All denture blanks had a smaller linear dimension from tuberosity-to-tuberosity when measured immediately after curing than the dimensions of the stone model upon which they were cured.

After storage in room temperature or body temperature water, denture blanks processed with tin foil on both sides showed the best adaptation when observed

directly or recorded photographically (Fig. 5, *a,e,i,* and *m*) but exhibited linear dimensional changes of the same order as denture blanks processed with tin-foil substitute on both sides which did not fit the model upon which they were processed (Fig. 5, *c,g,k,* and *o*).

The linear dimensional changes measured on some of the types of denture blanks which had the poorest adaptation were smaller than the linear dimensional change recorded for denture blanks which preserved their good adaptation.

One series of measurements is illustrated graphically in Fig. 8, *B,* where the linear dimensional change in per cent, as obtained from measurements from tuberosity-to-tuberosity (broken lines) and from flange-to-flange (solid lines), is plotted

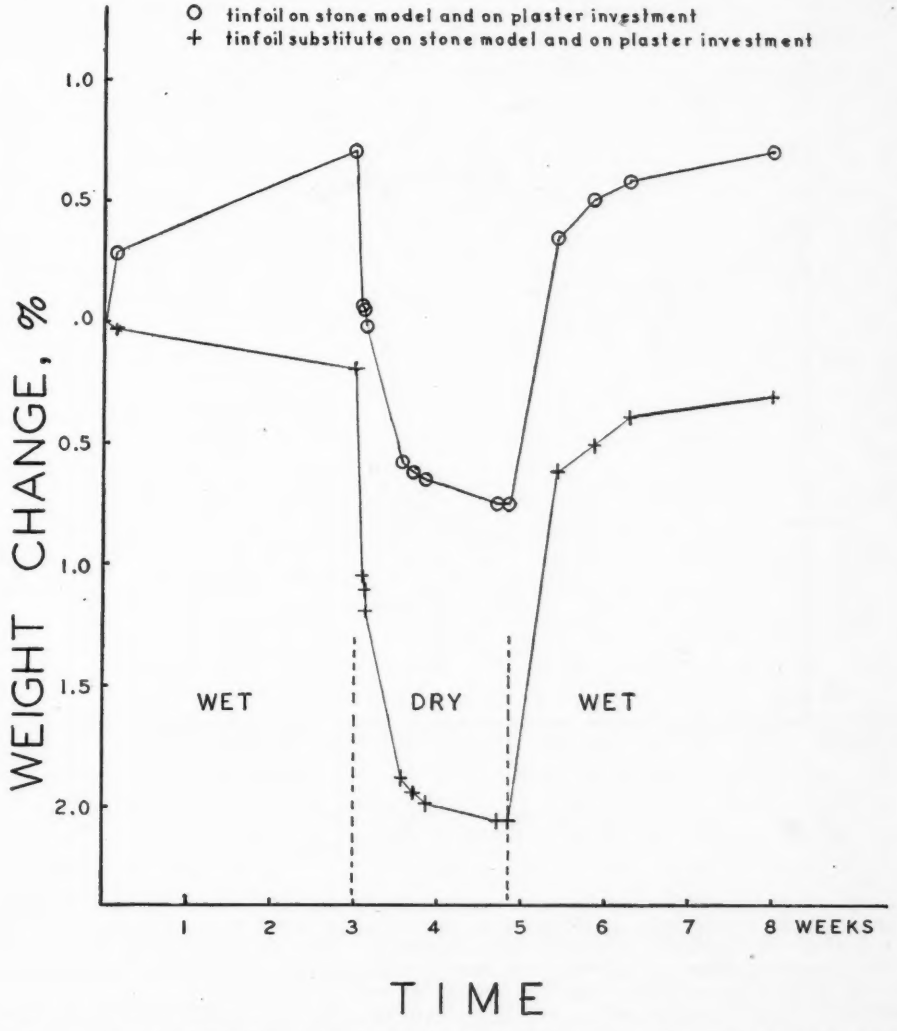
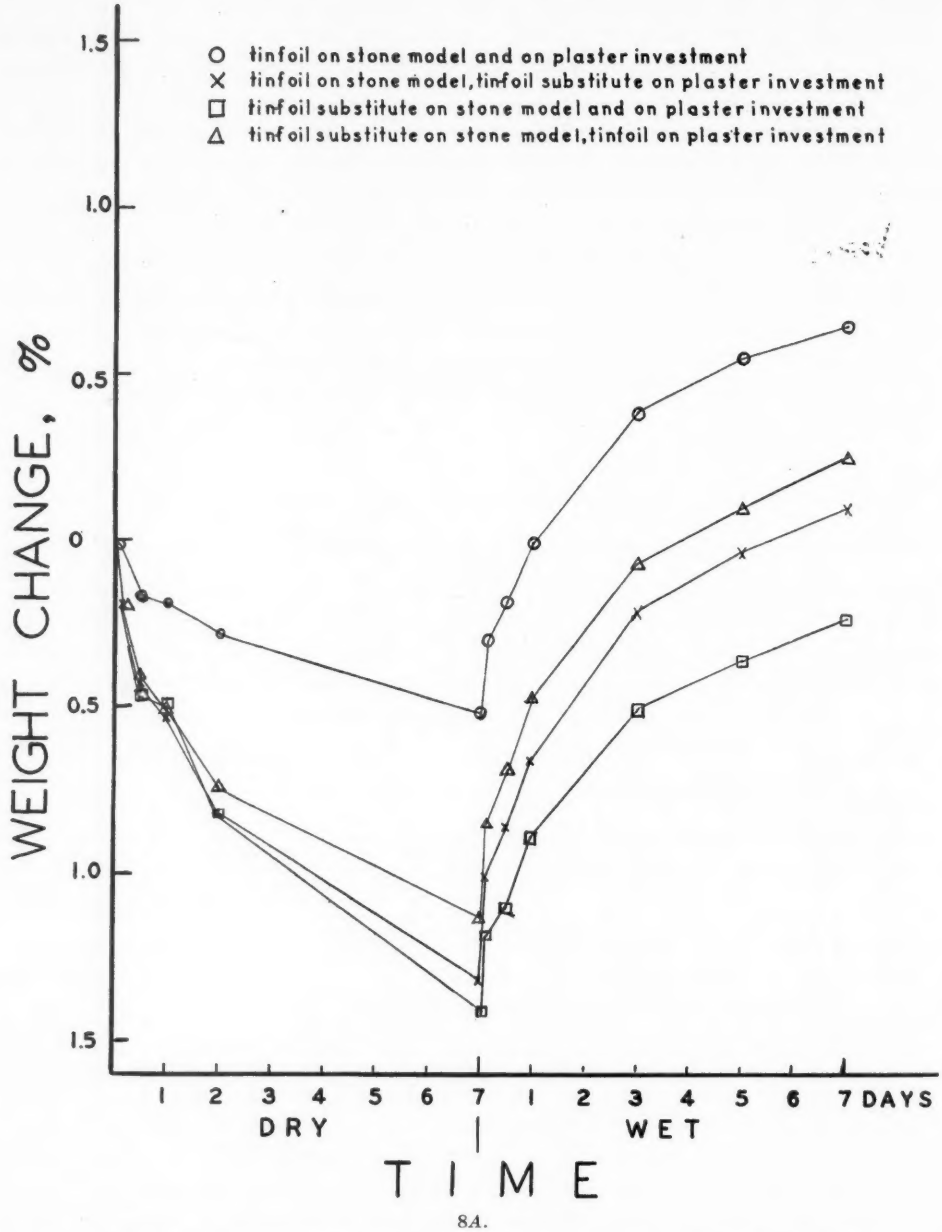


Fig. 7.—Graphic illustration of weight changes for denture blanks processed with tin foil or tin-foil substitute on both sides. The denture blanks were stored in water for three weeks, then desiccated until the weight became constant after which they were reimmersed in water. Processed for nine hours at 160° F., bench cooled for two hours before quenching.

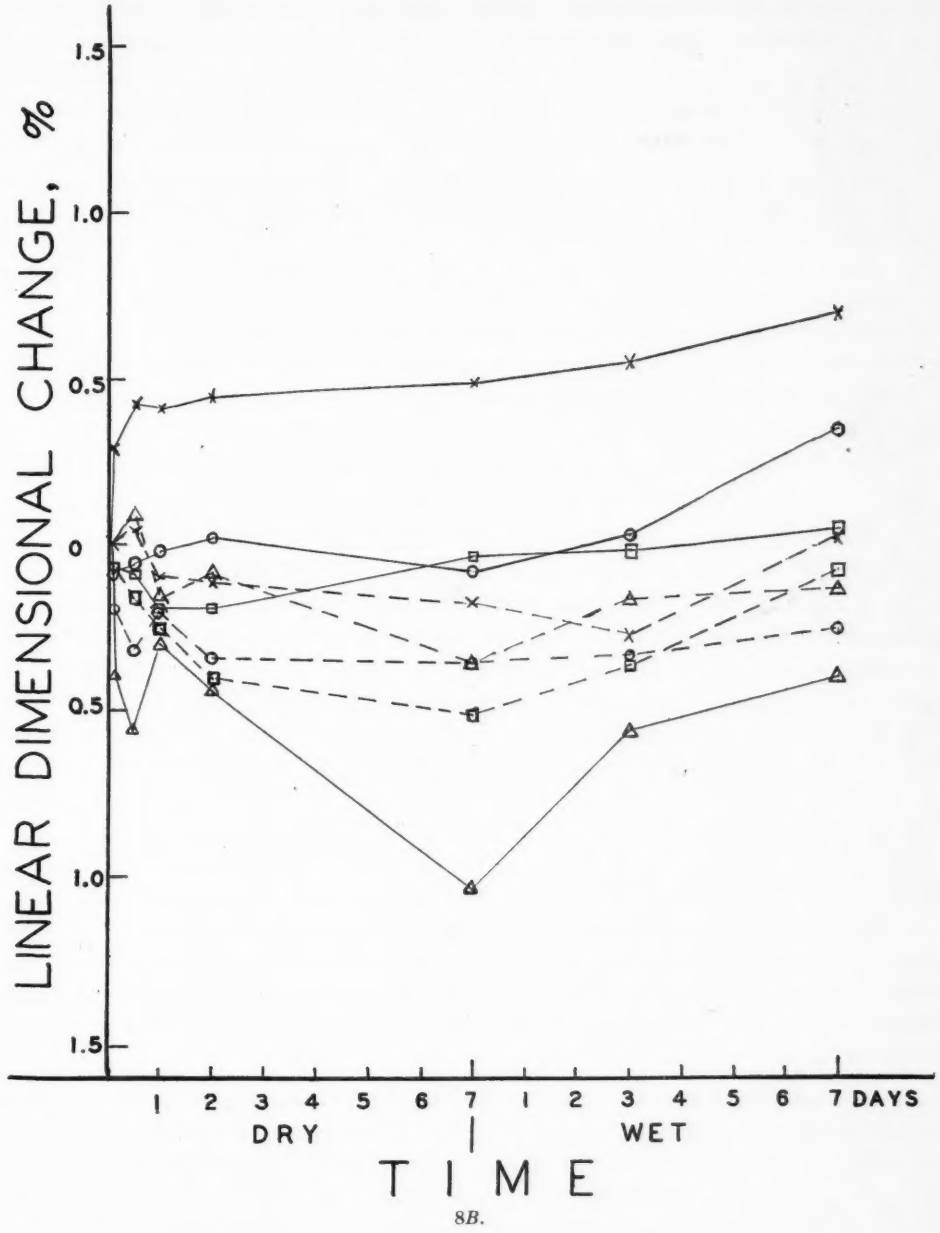


8A.

Fig. 8.—Graphic illustration of (*A*) weight changes and (*B*) linear dimensional changes from tuberosity-to-tuberosity (broken lines) and from flange-to-flange (solid lines) for four acrylic resin denture blanks, processed for nine hours at 160° F., bench cooled for two hours before quenching, placed in desiccator at body temperature immediately after deflasking, and transferred to water at body temperature after one week's desiccation.

against time, for a set of four specimens desiccated for one week, then stored in water at body temperature for one week.

The set of four specimens used for these recordings exhibited the same type and degree of change of adaptation as did the set shown in Fig. 5.



8B.

As an example of the lack of relationship between linear measurements and adaptation the resultant curves should be studied.

According to the curves, the denture blank processed against tin-foil substitute on both sides shows the least linear dimensional change at the end of two weeks, but the actual adaptation of this denture blank was definitely inferior to that of the two denture blanks which were processed with tin foil on the stone model (tin foil or tin-foil substitute on the plaster investment).

Apparently the dimensional changes responsible for the difference in adaptation of the denture blanks at different stages occur in three dimensions in several planes and in such a manner that the dimensional changes recorded linearly between different measuring points across the posterior of the specimens are *not* representative of the total changes.

The linear measurements from flange-to-flange or from tuberosity-to-tuberosity are not true indications of the adaptation of the denture blanks.

CHANGE OF WEIGHT

Upon storage in water specimens processed with tin foil on both stone model and plaster investment showed a gain of weight (average of three specimens: 0.8 per cent over original weight). Upon desiccation such specimens lost more weight than they had gained by storage in water (final weight: 0.8 per cent below original weight). Upon reimmersion the weight again increased to the same total weight as recorded after the first storage in water.

Denture blanks processed with tin-foil substitute on one or on both sides did not increase in weight, or, in somes cases, lost weight after storage in water. Such loss of weight is interpreted as possibly resulting from a slight solubility of the acrylic resin in water. Fig. 7 illustrates the weight changes typical for specimens processed against tin foil on both sides and against tin-foil substitute on both sides. Both specimens were immersed in water immediately after processing and stored at body temperature for three weeks. They were then transferred to a desiccator and kept there until the weight became constant, then reimmersed in water.

A different pattern of behavior was noticed when denture blanks were desiccated immediately after deflasking.

Fig. 8, *A* shows a typical graph of the weight changes for a set of four specimens which were desiccated immediately after deflasking. The weight of the denture blanks processed with tin-foil substitute on the stone model, or on the plaster investment, or on both, decreased two to three times as much as did the weight of the denture blank processed with tin foil on both sides.

Consequent storage in water caused all types of denture blanks to gain weight in approximately the same proportion. The weight of specimens processed against a tin-foil substitute would thereby approximate its weight immediately after processing, whereas specimens processed against tin foil on both sides would finally reach a weight about 0.8 per cent above the original weight. Specimens processed with tin foil on one side would fall between these values, as exemplified in Fig. 8,*A*.

The fact that denture blanks processed against tin-foil substitute changed very little in weight upon their first immersion in water and lost as much weight upon desiccation as did denture blanks processed against tin foil (Fig. 7) bears out the conclusion that the former type of specimens was saturated with water during the processing.

The theory that curing shrinkage may be partly compensated for by water sorption, consequently cannot hold true for dentures processed in a mold lined with tin-foil substitute.

No relationship could be found between weight changes and linear dimensional changes as recorded across the posterior of the denture blanks (Fig. 8, *A* and *B*), nor between the actual adaptation of the denture blanks on their stone models and the weight change or linear dimensional change. This does not exclude the possibility that the water content of the acrylic resin is the factor responsible for internal stresses existing in this material after processing.

The evidence of internal stresses is seen in the warpage of specimens, as produced by time and temperature; the fact that warpage occurs in a similar manner whether the specimens are kept under dry or wet conditions of storage points toward the conclusion that internal stresses are set up during the processing, and that the type of mold-lining material and possibly the surface quality of the mold are factors determining the amount of stresses produced.

CONCLUSIONS

1. The best adaptation of denture blanks was obtained when tin foil was used as a lining material for both the stone model and the plaster investment.

2. Considerable warpage developed during storage of denture blanks processed with tin-foil substitute, and the acrylic resin was subject to crazing for at least 2 mm. in depth from the surface.

3. High processing temperature (212° F.) or immediate quenching in cold water caused warpage of denture blanks processed with tin-foil substitute, but caused no significant difference in denture blanks processed with tin foil.

4. Linear measurements across the posterior of a denture blank are not a true indication of its adaptation.

5. No water sorption was demonstrated after immersion in water of specimens processed with tin-foil substitute on both the stone model and on the plaster investment. The theory of compensation for curing shrinkage by water sorption cannot hold true for dentures processed with tin-foil substitute as a mold-lining material.

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PULP PROTECTION IN CROWN AND BRIDGE PROSTHESIS

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PERHAPS ONE of the greatest sources of irritation, to both the dentist and tooth pulps, has been the lack of adequate protective liners and cements for use between operative visits, and for permanent cementation. Both are just as important for successful crown and bridge prosthesis, as anesthetics are for patient comfort, and as a water spray is during operative procedures for increasing the efficiency of cutting tools while protecting the tooth against overheating.

The histologic analyses of pulpal tissue and dentine in response to various coagulants,[1] liners,[2] and cements[3,4] offer the dental profession the means for an objective evaluation of protective procedures. Heretofore, their evaluation depended upon each dentist's own subjective "feeling" about a particular protective based upon his "experience" with it. Unfortunately, the controls and interpretation of some histologic investigations are not as objective as they should be. Therefore, even in the face of such evidence, it is necessary to be discriminating in the choice of materials.

TEMPORARY CEMENTS

There are several good proprietary anodyne zinc oxide and eugenol preparations on the market. However, some of them incorporate desensitizing ingredients which are actually irritating to the pulp. The rationale of their use is to create a temporary mild irritation which in turn stimulates the laying down of secondary or irregular dentine by the odontoblasts in the pulp, thereby adding to the protection of the pulp.[2] Unfortunately, too many of these desentizing ingredients go beyond the desired amount of irritation. This results in pulpal inflammation which makes teeth hypersensitive and often causes the eventual death of a pulp.

In addition to being an anodyne to the pulp, there are several other considerations in the choice of a temporary cement. It must handle easily on mixing to any desired consistency, set rapidly when it is once seated over a prepared tooth which is wet with saliva, the excess must be easily flicked off, the temporary crown subsequently must be easily removed with an instrument, the preparation must be left clean with very little or no temporary cement remaining, and it must have no deteriorating effect on temporary crowns (particularly acrylic,[5] which are so popular today). A material that meets these requirements is made up of zinc oxide powder and a liquid of eugenol and rosin.

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DESENSITIZATION

Many chemicals have been investigated and tried for the desensitization of dentine, particularly in respect to the desensitization of exposed necks of teeth. Among these are sodium fluoride paste (33⅓ per cent), silver nitrate, and hot pure olive oil. Sodium fluoride paste, sealed into the cavity with a temporary cement after preparation, proved too irritating. However, other compounds of fluorine, in smaller concentration, which are washed off after application may prove efficacious after further investigation. The burnishing of hot pure olive oil onto sensitive necks of teeth has been meeting with success by many periodontists. The impracticability of this procedure in crown and bridge procedures is obvious. Silver nitrate coagulates the organic matter of the dentinal tubules thereby increasing the pain threshold to stimuli, and when it is reduced with eugenol or formalin, it has proved to be somewhat effective without irritating the pulp.[1] Where color may be a factor, as in a porcelain jacket crown or an acrylic open-faced crown, the Impregnol technique is indicated.

Cavity varnishes, although permeable to acids, have been shown to lessen the severity of pulpal irritation[2] while proving to be fairly effective in blocking off pathways to temperature radiations.

IMPERMEABLE OR REDUCING AGENTS

Oxyphosphate of zinc cement has been found to be the most effective bond between dental restorative materials and tooth structure, and with the least irritation. However, its irritating properties, desirable in shallow preparations to stimulate secondary dentin formation, can be detrimental to the health of a pulp in deep ones. Unfortunately, none of the desensitizing agents, either coagulants or varnishes, render the dentinal pathways impermeable to acid irritation. Two compounds that are effective in overcoming this problem are a thin mix of zinc oxide and eugenol, or suspensions of calcium hydroxide. The first forms of mechanical wall, while the latter forms a chemical barrier reducing the free acid of cement as well as mechanically plugging the dentinal tubules.[6]

CHRONOLOGICAL USE OF ALL AGENTS

After each tooth preparation, silver nitrate is applied and reduced by eugenol or formalin. The temporary crown is filled with a zinc oxide-eugenol-rosin cement and seated to place. The excess cement is removed after setting. After the patient's visit for the try-in of the crown, a second application of silver nitrate is made, and the temporary crown is replaced with the anodyne cement. At the patient's final visit, the silver nitrate application is repeated. Before the final cementation with oxyphosphate of zinc cement, the teeth are isolated, dried, coated with copal varnish, and painted with a suspension of calcium hydroxide. These materials are kept away from the last millimenter or two of the marginal areas. Logically, the calcium hydroxide should be applied first, but the varnish dissolves it. The permanent crowns, previously machined out to allow space for the medication and

cement except for the last milimeter or two nearest to the margins are loaded with zinc oxyphosphate cement and seated to place.

Patient comfort and the maintenance of pulpal health go hand in hand. It is the dentist's responsibility to employ every possible means by which these ends may be attained. Particularly where the trend for recognizing the validity of more extensive tooth preparations (full coverage) and of more extensive reconstruction crown and bridge prosthesis is ever on the increase. Adequate pulp protection is only one of the means to justify the ends of crown and bridge prosthesis. Failure to protect the pulp alone can nullify the value of crown and bridge prosthesis in its proper place, which is so important to good oral health and function.

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Paragraph Clinics

THERE are many ways by which the little everyday problems in prosthetics may be solved. Your solutions to these problems will be helpful to others. They may be shown by one picture and one descriptive paragraph in the *Paragraph Clinics* section of the JOURNAL.

THROWAWAY IMMEDIATE DENTURE

G. E. TILTON, D.D.S.

Wichita, Kan.

MORE AND MORE PATIENTS are asking for immediate dentures, and yet at the same time, they are asking to be hospitalized, and have all teeth removed in one operation. Some surgeons are encouraging this procedure, and the following technique will enable the prosthodontist to meet these demands.

1. A full alginate impression is made.

2. Tooth acrylic of the selected color is either poured or brushed into the impression of the teeth.

3. Plaster or stone is poured into the impression, and at the same time, the impression is set on the lower half of an occluding frame that will maintain the vertical dimension.

4. The impression is removed, and the teeth (formed in step 2) are attached to the upper half of the occluding frame.

5. The teeth are removed from the cast and trimmed around their gingival margins. The cast is trimmed as desired.

6. The acrylic teeth are placed in position on the upper part of the occluding frame. The occluding frame is closed, and the teeth are attached to the cast by quick-curing acrylic. The entire denture is then "brushed on" with quick-curing acrylic.

7. Missing teeth may be added, and the denture may be relined when it is necessary.

1006 UNION NATIONAL BANK BLDG.
WICHITA 2, KAN.

Received for publication Jan. 7, 1954.

The Readers' Round Table

Chicago, Ill.

Editor, The Journal of Prosthetic Dentistry:

I have received several letters and inquiries from dentists relating to an advertising circular mailed to the profession by the Perfected Dental Products Co., 32 North State Street, Chicago 2, Ill.

Illustrations and quotations from my paper which was published in July issue, THE JOURNAL OF PROSTHETIC DENTISTRY (**2**:491, 1952) were used in this circular, and apparently there is a supposition that I am directly interested in this organization.

I wish to make it clear that I have no connections whatsoever with this company and the only compensation ever received was some samples of their products left in our laboratory for testing.

Your very truly,
E. BYRON KELLY, D.D.S.

ANNOUNCEMENT

Two residencies will be offered to qualified Dentists at the Bronx Administration Hospital, Bronx, New York, beginning July 1, 1954. One residency will be Oral Surgery, the other in Prosthetics.

Candidates must have completed an internship in an approved Hospital or have attended at least one academic year's post graduate training in an approved Dental School.

The residencies shall be for two calendar years. The stipends are: Junior Resident, $2400 per annum. Intermediate Resident, $2970 per annum. Senior Resident, $3300 per annum.

For further information and application blanks address, Chief of Dental Service, Veterans Administration Hospital, 130 W. Kingsbridge Rd., Bronx, N.Y.

ANNOUNCING

THE AMERICAN DENTURE SOCIETY PROSTHETIC ESSAY CONTEST

PRIZES WILL BE AWARDED to the two senior dental students who submit the best essays on prosthetic dentistry. The first prize is Five Hundred Dollars ($500.00) and the second prize is Three Hundred Dollars ($300.00). The purpose of the contest is to stimulate technical writing by dental students.

RULES

1. The contest is open to all senior dental students of American dental colleges.
2. Essays are to be on some phase of prosthetic dentistry.
3. Essays are to become the property of The American Denture Society. None will be returned.
4. The winning essays will be published in THE JOURNAL OF PROSTHETIC DENTISTRY.
5. Essays must be double spaced, on plain paper, with generous margins. No carbon copies or essays on onion skin paper will be considered.
6. Illustrations must conform to the standards of THE JOURNAL OF PROSTHETIC DENTISTRY.
7. Essays must be worthy of publication in THE JOURNAL OF PROSTHETIC DENTISTRY to qualify for a prize.
8. Essays must be postmarked on or before July 15, 1954 in order to receive consideration.
9. The judges of the contest are a special committee of The American Denture Society.
10. The decision of the judges is final.
11. Essays are to be clearly marked as "Contest Papers" and sent to: Dr. Carl O. Boucher, College of Dentistry, The Ohio State University, Columbus 10, Ohio.

For further information write to: Dr. Arthur L. Roberts, Secretary, American Denture Society, Aurora National Bank Bldg., Aurora, Ill.

News and Notes

ANNOUNCEMENTS

The Academy of Denture Prosthetics will meet April 12 to 16, 1954, at the Roney Plaza Hotel, Miami Beach, Fla.

The Pacific Coast Society of Prosthodontists will hold its Annual meeting at the College of Dentistry, University of Washington in Seattle, Washington, May 29 and 30, 1954.

The Southeastern Academy of Prosthodontics is scheduled to hold its Scientific Meeting, March 20, and 21, 1954, at the Atlanta Biltmore Hotel in Atlanta, Ga. Attendance to the Scientific Session is open to dentists other than members of the Academy as guests of the Academy upon payment of the registration fee. For further information write to Dr. Ralph W. Durham, Secretary-Treasurer, 1001 Bankers Ins. Bldg., Macon, Ga.

The Ohio State University College of Dentistry will hold its Tenth Post College Assembly on April 21 and 22, 1954. This meeting is a refresher for the alumni, but is open to all ethical dentists. For further information write to Dr. William C. Dew, College of Dentistry, Ohio State University, Columbus 10, Ohio.

The American Association for Cleft Palate Rehabilitation will hold its Twelfth Annual meeting May 14 and 15, 1954, at the Webster Hall Hotel in Pittsburgh, Pa. The program is under the direction of Dr. S. M. Dupertuis, 3700 5th Ave., Pittsburgh, Pa. For further information write to the Secretary, Jack Matthews, Psychology Department, University of Pittsburgh, Pittsburgh 13, Pa.

The Dental Program of the Extension division of the University of California at Los Angeles announces an eight week refresher course in dentistry starting in April, 1954. This course will include lectures in fifteen (15) subjects and clinical and laboratory procedures involved in Operative Dentistry, Crown and Bridge, and Prosthetics. For further details write to J. Eugene Ziegler, D.D.S., Head Dental Extension, Room 211, 815 South Hill St., Los Angeles 14, Calif.

Columbia University Dental School announces the First Rose Cohen Memorial Lecture to be held at 8:00 P.M., March 31, 1954. The essayist is to be Dr. Robert Moyers, Professor of Orthodontics at the University of Michigan; his subject will be "The Physiology of Centric Relation." All members of the dental profession are invited.